PERIODICAL Nat. Res. Coun. Pacific Sci. Bd.
Atoll Res. Bull

Nos. 41, 42, 43, 44, 45, 46 August 15, 1955

#41-46 #41-46

ATOLL RESEARCH BULLETIN

41. *Canton Island, South Pacific*
by Otto Degener and Edwin Gillaspy

42. *The insects and certain other arthropods of Canton Island*
by R. H. Van Zwaluwenburg

43. *The natural vegetation of Canton Island, an equatorial Pacific atoll*
by William H. Hatheway

44. *The hydrology of Ifalik Atoll, Western Caroline Islands*
by Ted Arnow

45. *A partial list of the plants of the Midway Islands*
by Johnson A. Neff and Philip A. DuMont

46. *Conspicuous features of organic reefs*
by J. I. Tracey, Jr., P. E. Cloud, Jr. and K. O. Emery

AUG 1955 LIBRARY POFI FISH & WILDLIFE SERVICE

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences—National Research Council

Washington, D. C., U.S.A.

ATOLL RESEARCH BULLETIN

---

41. Canton Island, South Pacific

by Otto Degener and Edwin Gillaspy

42. The insects and certain other arthropods of Canton Island

by R. H. Van Zwaluwenburg

43. The natural vegetation of Canton Island, an equatorial Pacific atoll

by William H. Hatheway

44. The hydrology of Ifalik Atoll, Western Caroline Islands

by Ted Arnow

45. A partial list of the plants of the Midway Islands

by Johnson A. Neff and Philip A. DuMont

46. Conspicuous features of organic reefs

by J. I. Tracey, Jr., P. E. Cloud, Jr. and K. O. Emery

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences--National Research Council

Washington, D. C.

August 15, 1955

ACKNOWLEDGMENT

It is a pleasure to commend the far-sighted policy of the Office of Naval Research, with its emphasis on basic research, as a result of which a grant has made possible the continuation of the Coral Atoll Program of the Pacific Science Board.

It is of interest to note, historically, that much of the fundamental information on atolls of the Pacific was gathered by the U. S. Navy's South Pacific Exploring Expedition, over one hundred years ago, under the command of Captain Charles Wilkes. The continuing nature of such scientific interest by the Navy is shown by the support for the Pacific Science Board's research programs, CIMA, SIM, and ICCP, during the past seven years. The Coral Atoll Program is a part of SIM.

The preparation and issuance of this Bulletin is assisted by funds from Contract N7onr-29154.

The sole responsibility for all statements made by authors of papers in the Atoll Research Bulletin rests with them, and do not necessarily represent the views of the Pacific Science Board or of the editors of the Bulletin.

Editorial Staff

F. R. Fosberg, editor
M. H. Sachet, assistant editor

Correspondence concerning the Atoll Research Bulletin should be addressed to the above

c/o Pacific Science Board
National Research Council
2101 Constitution Avenue, N. W.
Washington 25, D. C., U.S.A.

ATOLL RESEARCH BULLETIN

No. 41

Canton Island, South Pacific

by

Otto Degener and Edwin Gillaspy

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences--National Research Council

Washington, D. C.

August 15, 1955

CANTON ISLAND, SOUTH PACIFIC

By

Otto Degener [1] and Edwin Gillaspy [2]

Mr. Garrison Costar, Engineer with the Civil Aeronautics Administration, in June 1950 commissioned Mr. Otto Degener, Collaborator in Hawaiian Botany of the New York Botanical Carden, to cover Canton Island with vegetation. Degener consulted with Col. Edwin H. Bryan, Jr., for firsthand information regarding the atoll. Bryan had visited Canton as early as 1924 for study and, when the "Southern Cross" was about to fly south in 1928, advised Sir Charles Kingsford-Smith to select this atoll as the best emergency landing place between Hawaii and Fiji. Degener flew from Honolulu to Canton for a week's stay in July 1950 - a distance of 1,630 nautical miles - with Mr. Costar and Mr. William H. Hatheway, a graduate assistant in botany at the University of Hawaii, whom he had selected as the man best qualified to assist him.

Degener returned to Canton for six weeks in April and May of 1951 to continue his biological studies and to prepare the present paper jointly with Mr. Edwin Gillaspy, then Island Manager, who is most familiar with the administrative and non-biological aspects of the island. The following pages contain a conglomeration of personal observations and a compilation of observations already in print by others or recently expressed to the two writers by various observant friends.

PURPOSE

Now that Canton Island is the site of an important airfield, there are two reasons for wishing to cover its bare wastes of coral rock and sand with plants. First, a cover of vegetation will stabilize the land. It will keep the sand from blowing about and away, and from penetrating costly wireless transmitters and other instruments to foul them. Second, it will be a boon to the 300-odd people stationed there. They will no longer be obliged to inhale clouds of dust nor be exposed to glare so intense as to cause in some cases symptoms of snow blindness. It will make living there much more pleasant and worthwhile.

1/ New York Botanical Garden

2/ Civil Aeronautics Administration

TOPOGRAPHY

Canton is the most northern of eight low coral islands known as the Phoenix Islands and lying between latitude 2° 30' and 4° 40' S., and longitude 170° 40' and 174° 40' W. It is a typical atoll with presumably a volcanic core. Its fringing reef rises so abruptly from the deep in most places that effective anchorage facilities are practically lacking for a vessel too large to enter the lagoon.

In 1943 one natural channel through the rim of the island was deepened by dredging, and a new one cut so that sea-going vessels not exceeding 420 feet in length can now tie up at a wharf 385 feet long in the lagoon. The current, however, through the channels between lagoon and open ocean can be very strong and treacherous, running at six to eight knots at flood and ebb tides. Ebb currents likewise produce a marked rip when mixing with the ocean currents up to a mile or more off the channel entrance. The hazard to which ships are exposed at Canton is apparent. In 1942, the SS "President Taylor", formerly the "President Polk", under contract from the President Lines to the United States Army as a troop ship, was caught in the channel current while trying to disembark troops as close to shore as possible because of enemy submarine danger. As a result she piled up on the reef at the entrance of the channel with her bow 270 yards from Musick Light. Salvage operations were abandoned when attempts to refloat her proved unsuccessful. The Army and Navy personnel, numbering up to 10,000 on Canton, soon stripped her of all usable gear, and to this day odd pieces of ship furniture and ventilators may be seen still in use on the island. A Japanese submarine once in late 1942 ineffectually shelled the useless hulk. The "President Taylor" became a favorite haunt for an afternoon of fishing or to while away a few hours from duty by island residents until it was gutted by fire in May 1948, rumored to have started from the explosion of an illicit whiskey still in her hold. She burned four days. The rusted and fire-blackened wreck then served as the most prominent landmark of the island, her funnel and masts being visible for eighteen miles at sea. In 1954, according to Mr. William J. Evans, the present U. S. Resident Administrator, the vessel is being cut up for scrap and hauled away.

Canton has been likened in shape to a pork chop. Its rim, now served with an auto road, is 150 to 1,800 feet wide. This encloses a lagoon of twenty-five square miles, which is about eight miles long and four miles wide at the west end. Until dredged out to a depth of about ten fathoms near the dock and the 1,600 by 1,800 foot ship turning basin, the lagoon was badly choked up with live coral near the entrances where the fresh ocean water enables the organisms to grow. The natural

depth of the lagoon is seldom more than two and a half fathoms, and extensive whitish mudflats, inhabited by colorful fiddler crabs, adjoin the shore. The lagoon, warmer than the surrounding ocean, is stocked with fish of many kinds, as well as with sting rays and sharks which last make swimmers keep a sharp lookout.

The island rim varies in height from twenty to ten feet or less. At certain areas along the outer or seaward coasts, where the waves hit the shore with great violence during storms, large flat polished boulders of broken reef, of breccia consisting of reef fragments, of hardpan consisting of consolidated sand, and tridacna clam shells are piled up to considerable heights. The inner shore slopes gently to the lagoon, ending in a white sandy beach or in low ledges of overhanging rock. The island has no supply of fresh water except the little that may be trapped during showers in upturned tridacna shells - natural Holy Water fonts. Such water, due to the humid atmosphere, evaporates but slowly during the day.

The average annual rainfall of about 19 inches is sparse for a tropical latitude and there is a scarcity of fresh water. To augment the supply that is caught in the form of rain from roofs of buildings and led into individual cisterns, both the Civil Aeronautics Administration (CAA) and the Pan American World Airways (PAA) have elaborate installations for the distillation of fresh water from the sea. This is a costly process making, of course, the watering of garden plants impracticable. An indication of the costliness of this process is shown by the fact that one good shower in April 1951 saved PAA about $3,000 in distillation costs.

The surface soil of Canton contains not a particle of autochthonous or native lava, notwithstanding the island's presumed igneous foundation. But here and there, particularly along the windward shores, are fragments of pumice. These are mostly tawny in color and less than six inches in diameter, though a few may be as large as a man's head. Several rounded pieces about a foot in diameter, for example, were discovered by Dr. S. G. Ross in April 1951. Such stones have been cast ashore after having floated here from some actively volcanic region perhaps thousands of miles distant. Another unexpected though extremely rare source of foreign soil is rocks embedded in the firm grasp of the roots of trees that have washed ashore. One large tree observed had transported six rocks, about a foot in diameter, to the island. Two of these rocks crumbled into fragments upon being hit with a club.

The surface of the land varies. The finest calcareous "clay" or silt occurs chiefly along the lagoon. Light, readily blown, pink sand consisting of Foraminifera shells of the genus Baculogypsina, and less abundantly of Spaerulata lessoni

and a species of Heterostegina, is common along the beach and far to the lee of it. It sifts in among coral fragments, shells and rubble. But where these are exposed to the full force of the wind, this pink sand hardly covers them, being blown away to find a wind-free resting place elsewhere. Canton, by the way, is the farthest north from which the almost microscopic organism, Baculogypsina, is yet known. The coral fragments are of all sizes up to about five inches in diameter. Elsewhere, especially along the beach, occur wave worn, solid platforms of consolidated reef fragments and sand half a mile and more long. The soil consists mostly of calcium carbonate derived from marine animals and plants comminuted in the main by wave action. In addition, there are extensive thin areas of porous hardened guano, the legacy left by myriads of sea birds of past ages. Such deposits were formerly exploited by man for fertilizer. The ruins of a stone wharf, perhaps built about 1870 and jutting out into the lagoon, and rusted iron rails overgrown with kou tree trunks remain today as a souvenir of this industry on the north central side of the island. Here and there are smaller but distinct areas of decayed vegetation forming an acid, moisture holding humus. Around large boulders, logs or other objects casting shade, is a very curious friable and rare soil consisting of the accumulated excrement of the terrestrial hermit crab (Coenobita perlatus) that may congregate by the hundreds in such situations during the heat of the day. Thus Canton soil varies from basic all the way to very acid, depending to what extent these types of soil are intermixed. Areas of acid soil, however, are very sparse indeed. In addition, these types of soil and their mixtures bear a trace to very high concentrations of salts derived from ocean spray, from flooding, and from capillary rise from the water table. These soils are rarely if ever leached out by an adequate supply of rainfall.

In many regions of the atoll the loose sand grains are cemented together to form at various depths a sidewalk-like hardpan. This cannot be penetrated by deep taproots, thus giving advantage to plants with shallow spreading roots or to quick-growing annuals that complete their entire life span after a few strong showers have drenched the upper inches of ground.

Canton, situated at latitude 2° 46' S., is sun baked. This, and the fact that many areas have been cleared of the little native vegetation they ever possessed by the bulldozers of the military during the war, makes the glare from the alabaster-white ground still more intense. The resulting heat, coupled with the warm water of the lagoon, causes a current of warm air to rise.* When large rain clouds approach such an island during the day, they sometimes split, drift around the island, and then coalesce again as they have passed; or if

* See Appendix A, p. 51.

these clouds are small, they tend to skirt the edge of the island, shedding most of their rain in the ocean. On the other hand at night, when the island heat no longer rises appreciably, the clouds no longer bypass the island and thus most of the rain falling on it consists of light night showers. Covering the island with more vegetation will slightly increase the fall of rain during the day which, in turn, will promote a slightly better growth of vegetation, a very desirable condition. If it were not for the warm water of the lagoon, almost landlocked, such an increase might be as much as six to ten inches annually. In time it may be found practicable to construct channels through various narrow parts of the rim into the lagoon to cool its waters, to reduce the salinity so as to increase plant and indirectly fish life, and to reduce the hazardous current that ships must now buck to tie up at the wharf.

Due to man's changes in the surface of Canton, it will be interesting to compare the future climate with that of the past. The following tables are reproduced from "Local Climatological Data", U. S. Weather Bureau, 1954.

Some weather statistics for early years, not shown below, have been consulted also. These, however, appear to be garbled in several instances. It is thought by some that for two years the figures for barometric pressure may have been added in error to rainfall, giving unusually high and spurious records of 80 and 100 inches. Be that as it may, the average rainfall based on carefully kept records is but 19 inches, with a recorded low of 8.71 inches in 1938 and a high of 35.97 in 1953. Most of the precipitation falls in showers during the period from March to August, with April and May often the wettest months. When the rainfall is scant during these two months, then the island vegetation becomes truly dry and sere.

Lightning and thunder are rare; hurricanes are unknown. Barometric pressure, following an almost regular semidiurnal tide-like movement, is worthless as an indication of weather changes. Average visibility is from 12 to 30 miles. Low clouds are few, and fog or mist is unknown. A haze, known to Hawaiians as ehukai and caused by salt particles cast into the atmosphere by waves breaking on the reef, may at times prove troublesome to land aircraft.

The air temperature is practically constant throughout the year, reaching about 88° F., in the afternoon and dropping to 78° F. at night. The following shows the temperature, taken over a period of eight years.

The prevailing winds blow from E.N.E. to E.S.E. West win are very rare. The breeze is usually a steady one of 12 to 14 miles per hour. This refreshing breeze makes this equatorial

atoll livable for man. It makes it more difficult for plants, however, to retain in their tissues the scant amount of water they have absorbed from the soil.

Because of local weather conditions, such as strength and direction of wind, it is difficult to predict the tide and current accurately for navigation. The mean high water interval is exactly 5 hours. The mean range is 3.3 feet, and the spring range is 4.0 feet. As there are but two breaks through the surrounding rim of land into the lagoon, the movement of water within the lagoon lags behind the ocean tides. When driving along the narrow southwest rim of the atoll with both expanses of water in full view at close range, the difference in water level between lagoon and ocean is at times so great as to look strangely unnatural. Because of the great shallow expanse of almost landlocked seawater exposed to the tropic sun, the lagoon water is far saltier than that of the open ocean.

The influence of the tide is noticeable throughout the entire rim of the island, no matter where test holes are bored to the water table. From tests made in early 1950 by Dr. L. H. MacDaniels, we find that the salt content varies tremendously on or in the rim. That of water from the open ocean has (as chloride) 20,300 mg. of chlorine per liter. Water from a drying pool at the extreme southeast end of the island was actually supersaturated and had a content of 90,000 mg. That of the Frigate Pool, where the birds with open beaks and lowered heads swoop down to dip up a drink of water in their lower bills measures but 4,200 mg. The new British well, three hundred feet northwest of the old one and three hundred feet from the lagoon, had only 2,000 mg., at a depth of three feet.

HISTORY

As prehistoric ruins prove, Sydney and Hull Islands, south of Canton, were evidently inhabited for some time by Pacific islanders before the coming of the white man. There is, however, no good evidence to show that such islanders ever lived on Canton for any length of time, though according to Carl E. Meinicke* quadrangular ruins of large coral blocks occur there which he considers as certainly ancient temples. Such people, with the aid of a large shell, could have dug down to potable, though salty, water. Whether they did so no one presently knows.

The whaler "Phoenix" discovered Winslow Reef, northwest of Canton, in 1851, and the name of this vessel became attached to the entire group of islands. As guano had become a commodity of great value, the American Guano Company, the United States

---

*Meinicke, C. E. Die Inseln des Stillen Ozeans. 2 : 265 - 268. 1888.

LATITUDE 2° 46' S
LONGITUDE 171° 43' W
ELEVATION (ground) 9 feet

METEOROLOGICAL DATA FOR THE CURRENT YEAR

CANTON IS., SOUTH PACIFIC
TOPHAM FIELD
1954

Month	Temperature: Averages: Daily maximum	Daily minimum	Monthly	Extremes: Highest	Date	Lowest	Date	Degree days	Precipitation: Total	Greatest in 24 hrs.	Date	Snow, Sleet, Hail: Total	Greatest in 24 hrs.	Date	Relative humidity: 1:00 a. BST	7:00 a. BST	1:00 p. BST	7:00 p. BST	Wind: Average hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Date	Percent of possible sunshine	Average sky cover sunrise to sunset	Number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet, Hail 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Maximum: 90° and above	32° and below	Minimum: 32° and below	Zero and below
JAN.	90.2	77.3	83.8	92	25#	74	19	0	0.43	0.22	23-24	0.0	0.0		82	80	65	77			32	ESE	27		5.9	5	15	11	7	0	0	0	21	0	0	0
FEB.	88.4	77.0	82.7	92	27#	73	10	0	0.20	0.18	9-10	0.0	0.0		80	82	66	76			23	ENE	17		6.1	6	11	11	4	0	0	0	10	0	0	0
MAR.	89.5	77.9	83.7	95	13	76	23	0	0.09	0.05	31	0.0	0.0		81	80	65	76			27	ENE	19		5.1	10	15	6	4	0	0	0	15	0	0	0
APR.	89.1	77.6	83.4	93	15	75	27#	0	1.09	0.50	27	0.0	0.0		84	84	66	79			22	ENE	11		5.7	7	14	9	5	0	0	0	12	0	0	0
MAY	90.3	78.7	84.5	93	19#	75	2	0	0.35	0.21	2	0.0	0.0		82	86	70	80			19	NE	11		5.4	7	17	7	4	0	0	0	22	0	0	0
JUN.	89.5	77.7	83.6	94	14	71	5	0	0.82	0.46	5	0.0	0.0		79	79	64	75			28	ESE	28		3.9	16	13	1	3	0	0	0	11	0	0	0
JUL.	88.3	77.8	83.1	92	11	74	26#	0	2.27	1.44	22-23	0.0	0.0		81	81	66	77			28	ESE	22		5.7	7	15	9	8	0	0	0	9	0	0	0
AUG.	88.7	77.1	82.9	94	6	73	21	0	1.98	0.63	3-4	0.0	0.0		80	80	64	76			22	ESE	13		4.7	11	15	5	11	0	0	0	8	0	0	0
SEP.	89.8	77.8	83.8	92	25#	76	28#	0	0.13	0.07	4	0.0	0.0		80	79	61	75			23	ESE	9		3.4	22	6	2	5	0	0	0	17	0	0	0
OCT.	90.4	78.1	84.3	97	29#	77	26#	0	0.24	0.15	31	0.0	0.0		75	74	58	71			21	E	27		4.9	13	12	6	3	0	0	0	20	0	0	0
NOV.	88.2	78.0	83.1	94	21	77	27#	0	0.03	0.03	21	0.0	0.0		77	75	62	73			23	ENE	4		5.1	8	15	7	1	0	0	0	9	0	0	0
DEC.	87.6	78.1	82.9	91	14#	75	3	0	0.16	0.15	3	0.0	0.0		76	75	61	73			23	ENE	27		5.4	5	20	6	2	0	0	0	8	0	0	0
Year	89.2	77.8	83.5	95	MAR. 13	71	JUN. 5	0	7.79	1.44	JUL. 22-23	0.0	0.0		80	80	64	76			32	ESE	JAN. 27		5.1	117	168	80	57	0	0	0	162	0	0	0

Ø Fastest observed one minute wind speed and its direction. This station is not equipped with automatic recording wind instrumen's

-7-

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet, Hail: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: 1:00 a. BST	7:00 a. BST	1:00 p. BST	7:00 p. BST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet, Hail 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 90° and above	32° and below	Min.: 32° and below	0° and below
(a)	(b)	(b)	(b)	8		8			(b)	13		13		8		8	8		8		8	8	8	8							8	8	8	8	8	8	8	8	8	8	8	8	8
J	88.0	78.0	83.0	98	1947	74	1954#		1.08	4.94	1940	T	1950#	1.99	1951	0.0	0.0		0.0		80	79	65	75							5.8	4	18	9	6	0	0	0	16	0	0	0
F	88.0	78.0	83.0	96	1952#	73	1954#		0.54	2.10	1949	0.04	1945	1.69	1949	0.0	0.0		0.0		80	80	64	76							5.6	5	17	6	5	0	0	0	12	0	0	0
M	88.5	77.6	83.1	96	1949	71	1953		1.92	9.34	1940	0.07	1951	1.86	1953	0.0	0.0		0.0		83	83	66	79							5.7	6	17	8	9	0	0	*	14	0	0	0
A	89.3	78.0	83.7	97	1951#	70	1953		3.78	11.50	1940	0.90	1945	4.15	1953	0.0	0.0		0.0		85	85	68	81							5.8	7	19	7	14	0	1	0	18	0	0	0
M	90.0	78.3	84.2	98	1953	71	1953#		2.86	8.33	1953	0.35	1954	2.09	1953	0.0	0.0		0.0		83	83	67	79							5.9	7	15	9	12	0	2	0	21	0	0	0
J	90.0	78.5	84.3	96	1953#	71	1954		2.80	5.26	1945	0.65	1947	1.78	1948	0.0	0.0		0.0		81	80	66	77							5.7	6	16	8	11	0	1	0	19	0	0	0
J	90.0	78.4	84.2	96	1953#	71	1952		2.33	5.73	1945	0.60	1947	2.12	1950	0.0	0.0		0.0		80	79	64	77							5.8	5	19	7	11	0	1	0	20	0	0	0
A	90.0	78.3	84.2	97	1951	71	1953#		2.40	6.78	1943	0.18	1949	2.00	1950	0.0	0.0		0.0		80	80	64	76							5.4	6	17	8	11	0	*	0	18	0	0	0
S	90.3	78.4	87.4	97	1952#	72	1953		0.69	1.69	1947	0.05	1950	1.51	1948	0.0	0.0		0.0		78	77	60	74							4.6	11	15	4	6	0	0	0	11	0	0	0
O	90.2	78.0	84.1	97	1951	73	1947		0.39	1.41	1953	0.03	1942	0.70	1953	0.0	0.0		0.0		78	75	60	74							5.1	10	15	6	5	0	0	0	22	0	0	0
N	89.3	78.0	83.7	98	1947	74	1947		0.27	0.97	1953#	T	1945	0.53	1952	0.0	0.0		0.0		77	75	60	73							5.4	7	18	5	4	0	0	0	18	0	0	0
D	88.0	78.0	83.0	95	1953#	71	1948		0.95	4.81	1939	0.06	1947#	1.81	1951	0.0	0.0		0.0		77	76	64	75							6.2	5	16	10	4	0	0	0	12	0	0	0
Year	89.3	78.1	83.7	98	MAY 1953#	70	APR. 1953		20.01	11.50	APR. 1940	T	JAN. 1950#	4.15	APR. 1953	0.0	0.0		0.0		80	79	64	76							5.6	76	202	87	98	0	5	0	201	0	0	0

(a) Length of record, years. (b) Normal values are based on the period 1921-1950, and are means adjusted to represent observations taken at the present standard location. Partial years' data, 1940 and 1942 considered in extracting maximum and minimum monthly precipitation values.

Pages 7 and 8 reproduced from "Local climatological data with comparative data 1954 Canton Island, South Pacific" issued by U. S. Weather Bureau, 1955

AVERAGE TEMPERATURE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
1947	84.9	84.8	85.3	85.2	84.8	85.0	84.4	84.2	84.2	83.6	84.0	83.8	84.5
1948	83.4	83.2	83.6	83.8	85.3	85.8	85.2	84.6	84.8	84.7	84.3	83.8	84.4
1949	85.2	84.9	83.9	83.9	84.4	84.8	84.9	84.4	84.6	83.6	83.5	83.2	84.3
1950	81.4	82.4	81.9	82.6	83.1	82.3	82.3	82.3	82.4	84.1	83.1	82.5	82.5
1951	82.8	83.3	83.4	84.7	85.2	84.2	85.2	84.6	85.8	85.1	85.9	83.6	84.5
1952	84.7	84.8	84.6	84.6	85.1	85.0	84.5	84.2	84.6	84.6	84.6	83.7	84.6
1953	84.6	84.1	83.5	84.1	83.7	84.4	83.7	83.7	84.7	84.9	84.8	83.6	84.1
1954	83.8	82.7	83.7	83.4	84.5	83.6	83.1	82.9	83.8	84.3	83.1	82.9	83.5
RECORD MEAN													
TEMP	83.9	83.8	83.7	84.0	84.5	84.4	84.1	83.9	84.4	84.4	84.2	83.4	84.1
MAX	89.3	89.1	89.1	89.9	90.7	90.4	90.3	90.0	90.6	90.6	90.0	88.6	89.9
MIN	78.4	78.4	78.3	78.1	78.3	78.3	77.9	77.8	78.1	78.1	78.3	78.2	78.2

TOTAL PRECIPITATION

CANTON IS., SOUTH PACIFIC
TOPHAM FIELD
1954

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1937									.85	.41	.41	.03	-
1938	.23	.18	.82	1.93	.57	2.38	.85	.55	.66	.27	.21	.06	8.71
1939	.15	.05	.10	1.58	3.75	1.55	3.01	1.79	.25	1.23	.30	4.81	18.57
1940	4.94	.75	9.34	11.50	2.92	4.80	3.03	3.04	-	-	-	-	-
1941	-	-	-	-	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	-	-	-	-	.15	.03	.37	.20	-
1943	.12	.17	.11	1.17	1.92	2.56	1.23	6.78	.30	.28	.60	.29	15.53
1944	2.96	.52	2.12	3.02	5.37	1.83	1.17	1.05	1.24	.08	.40	.74	20.50
1945	T	.04	1.21	.90	2.60	5.26	5.73	.54	.53	.61	T	.23	17.65
1946	-	-	-	-	-	-	-	-	-	-	-	-	-
1947	.17	.26	.08	1.59	.65	.65	.60	1.40	1.69	.89	.42	.06	8.46
1948	.86	1.24	5.99	10.32	4.44	3.19	1.20	3.18	1.64	.17	.06	.88	33.17
1949	T	2.10	1.16	2.16	3.45	1.00	.98	.18	.19	.09	.02	.17	11.50
1950	T	.29	.08	1.83	.44	2.36	5.50	4.04	.05	.16	.24	.10	15.09
1951	2.40	.32	.07	5.55	5.36	5.19	2.35	3.81	.77	.44	.22	3.88	30.36
1952	.19	.05	.97	2.67	5.21	2.10	3.23	3.48	.80	.79	.97	.27	20.73
1953	.77	.61	3.41	6.46	8.33	4.14	3.55	4.77	.65	1.41	.97	.90	35.97
1954	.43	.20	.09	1.09	.35	.82	2.27	1.98	.13	.24	.03	.16	7.79
RECORD MEAN	.64	.46	1.25	3.10	3.26	2.54	2.44	2.58	.68	.51	.34	.97	18.77

Records Sept. 1937 - April 1940 incl., Gilbert and Ellice Island Colony Administration (U.K.), 2° 49' S., 171° 43' W.; May-August 1940, US. Dept. of Interior, 2° 49' S., 171° 43' W.; Sept. 1942 - December 1945, U.S. Army Air Force at or within 2000 Ft of 2° 46' S., 171° 43' W. prior to August 1943 and at that location thereafter; Jan. 1947 - Present , U.S. Weather Bureau Office, 2° 46' S., 171° 43' W.

STATION LOCATION

Location	Occupied from	Occupied to	Airline distance and direction from previous location	South Latitude	West Longitude	Elevation above Sea level: Ground	Elevation above Sea level: Actual barometer elevation (H_a)	Elevation above Ground: Wind instruments	Extreme thermometers	Psychrometer	Telepsychrometer	Tipping bucket rain gage	Weighing rain gage	8" rain gage	Solar recorder	Remarks
BRITISH HEADQUARTERS RADIO	SEP 1937	PRESENT		2° 49'	171° 43'	-										Good exposure.
PRESENT HOTEL AREA, DEPT INTERIOR	SEP 1937	OCT 1940	-	2° 49'	171° 43'	-										Details not known.
HOTEL AREA IN BLDG, AT APPROACH TO FIRST SEA-PLANE DOCK (PAA)	SEP 1939	NOV 1941	-	2° 49'	171° 43'	-										
NAVY ADMINISTRATION BLDG (PAA EMPLOYEES IN NAVAL RESERVE)	NOV 1941	APR 1945	-	2° 49'	171° 43'	-										Move may have been a bit later than this.
TOPHAM FIELD, TERMINAL BLDG	MAY 1942	OCT 1946	-	2° 46'	171° 43'	9										AF station moved into terminal bldg. in July 1943. Prior location not known. Many details not known as part of this time Canton was a combat area.
" " "	OCT 1946	1/24/47	-	" "	" "	9	11									Between time AF abandoned station and the Weather Bureau took over with its own personnel, the WB contracted with PAA to man the station. On 12/28/46 the first WB employee arrived and on 1/24/47 the last PAA employee was relieved.
" " "	1/1/47	PRESENT	-	" "	" "	"	"	30	19	19			3	3	25	Good exposure.

This small land mass, being at most 20 feet above sea level, presents the minimum topographical influence.

REFERENCE NOTES

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation and snowfall in inches; wind movement in miles per hour; and relative humidity in percent.

Record mean values at the end of the Average Temperature and Total Precipitation tables are long-term means based on the period of record beginning in 1947 and 1938 respectively. Values have not been corrected for changes in instrument location listed in the Station Location table. Partial years' data, 1940 and 1942, not used in computing precipitation means.

Sky cover is expressed in a range of 0 for no clouds or obstructions to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3 tenths; partly cloudy days on 4-7 tenths and cloudy days on 8-10 tenths. Degree days are based on a daily average of 65° F. Sleet and hail were included in snowfall totals, beginning with July 1948.

Data for earlier years may be obtained by contacting the Weather Bureau Office for which this publication was issued.

Heavy fog in the Means and Extremes Table also includes data referred to at various times in the past as "Dense" or "Thick". The upper visibility limit for heavy fog is 1/4 mile.

* Less than one half.
\- No record.
\# Also on earlier dates, months, or years.
T Trace, an amount too small to measure.

Sale Price: 10 cents per copy. Checks and money orders should be made payable to the Superintendent of Documents. Remittances and correspondence regarding this publication should be sent to the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

NWRC, Asheville, N.C. --- 2/15/55 --- 350

Guano Company, and the Phoenix Guano Company were formed. Then in the Honolulu missionary publication "The Friend" of April 20 1859, and elsewhere, the claim of ownership by these companies of about fifty guano islands was recognized by the United State Government. It stated that these islands which "have become th property of citizens of the United States. . . have been recognized by the Government as pertaining to its territories under the act of Congress approved August 18, 1856." One of these islands now newly under the American flag was Mary's Island. Its longitude and latitude were given, and these practically coincide with those of Canton. When Mary's Island was actually first discovered by the white man is not known, but it must hav been previous to 1828 because that year it was listed in the Reynold's Report on page 12 as Mary Balcout's Island.

On March 4, 1854, the New Bedford whaleship "Canton", Capt. Andrew J. Wing, piled up on the reef of Mary Balcout's Island or, briefly, Mary's Island. After a short sojourn on the waterless island, the captain and crew took to their open boats and reached Guam after forty-nine days at sea. Commander R. W. Meade of the U.S.S. "Narragansett" surveyed Mary's Island in 1872, and at that time renamed the island "Canton" to commemorate the shipwreck eighteen years before. The name, though inappropriate, stuck. Unlike that of the city of southern Chin however, the name Canton is now pronounced with the first syllable accented.

As the supply of guano became depleted in the Phoenix Islands, the American companies abandoned them. John T. Arunde and Company, a London concern, then stepped in and took over th islands between 1883 and 1890, the British flag being hoisted and a protectorate declared. In 1916 Canton and the neighborin islands were leased for eighty-seven years to Capt. Allen of th Samoan Shipping and Trading Company. He planted some coconut trees, with the purpose of starting a copra industry. The last tree, now an erect dead trunk thirty feet high, survived until 1950. Because this tree was visible to ships at sea, Canton wa often known as the Lone Tree Island to sailors.

After Capt. Allen's death in 1925, the islands were again abandoned. But with aviation coming to the fore and the Phoeni Islands being possible airplane stepping stones between North America and Australia, the United States and Great Britain both became vitally interested in the Phoenix Group.

Though the British sloop "Leith" claimed Canton for the crown in 1936, when H.M.S. "Wellington" brought New Zealand scientists to this atoll on May 26, 1937 to study a solar eclipse, a U.S. Navy - National Geographic Society eclipse part aboard the Navy seaplane tender U.S.S. "Avocet" was already there. It had erected a concrete monument bearing embedded in it two American flags of porcelain enamel on stainless steel,

claiming ownership of the atoll for the United States. One flag faces the rising sun; the other, the setting sun. On one side of the cement block, at right angles to the flags, is the small brass seal of the National Geographic Society. On Memorial Day the monument was unveiled with appropriate ceremonies. The "Avocet" had selected the best anchorage in the channel and refused to move when the British demanded it. The British then fired a shot across the bow of the American vessel and, according to some reports, the Americans retaliated in like manner. Both captains, realizing that their behavior in this affair smacked of a Gilbert & Sullivan operetta, then wired their respective governments in London and Washington what to do next. Both received quite similar instructions to do nothing rash. Scientists of both nations then studied the eclipse of June 8, personally cordial though officially a bit cool. Then before departing to leave Canton to her sea birds and crabs, they left the flags of their respective nations flying, their flagpoles embedded firmly in stone foundations. In July the U.S. minesweeper "Swan" sailed to Canton in a vain search for the tragic Amelia Earhart Putnam and her navigator Fred Noonan. The following month Great Britain landed two radio operators and equipment there. The British Ambassador in Washington asked the U.S. State Department to remove the American markers claiming sovereignty. Instead of complying, President Franklin D. Roosevelt on March 3, 1938, put Canton, as well as neighboring Enderbury Island, under the jurisdiction of the Secretary of the Interior. Four days later four Americans of Hawaiian ancestry were disembarked from the U.S. Coast Guard cutter "Roger B. Taney" on Canton as colonists. On April 1 the Secretary of the Interior granted Pan American Airways a license to use Canton as a stop on the California-Hawaii-South Pacific flying route, all personnel to be American citizens.

Full title to Canton has not yet been settled. England claims ownership of the island because of her hoisting her flag on various members of the Phoenix Group, though not actually on Canton itself, between 1889-1892. The United States claims ownership because of discovery and advertised claims of ownership during whaling days, and particularly on the proclamation issued in the President's name on the general subject of islands, which reads as follows:

> "The first claim to title over undiscovered territory rests on the discoverer.
> 2. Under this point, many islands in the Pacific were first discovered by American flag ships.
> 3. The United States has always held that mere discovery does not give final title. If it is not followed by reasonable occupation it is insufficient.
> 4. In relation to the islands in question, of which there are many, the United States is assuming the right to occupy either because of (a) discovery,

(b) former occupation, or (c) failure of any other nation to occupy, or a combination of (a), (b), and (c)."

Differences regarding Canton were finally resolved between the two Powers on April 6, 1939, when U.S. Secretary of State Cordell Hull and British Ambassador Sir Ronald Lindsay signed a treaty whereby British aircraft are guaranteed equal use of American aviation facilities on Canton, the island to be an Anglo-American condominium for fifty years or until later modified or terminated. As a result, a distinct American and a distinct British community were built on the island in close proximity to one another on the southwest rim. The pioneer in this work was Pan American Airways, which commissioned the "North Haven" to leave San Francisco in May 1939 and to place a construction crew of forty-three and a great quantity of supplies on Canton. In seven months these men had built a modern hotel, a hospital and a radio station on Canton and had blasted dangerous coral heads out of the seaplane runway in the lagoon. The first plane flight occurred in August 1939. With outbreak of war, PAA service was temporarily suspended, and the Army and Navy made extensive improvements on the island. Thereafter the company resumed flights, operating under contract to the Naval Air Transport Service. In late 1942 Japanese submarines shelled the island thrice. On March 25, 1943, Japanese aircraft bombed the island, inflicting "slight damage."

The island was surveyed between March and July 1938 for the Department of the Interior and recently revised, chiefly vegetationally by Hatheway, see Fig. 1 of Atoll Research Bulletin 43.

As Canton provides the best facilities for landing both sea and land planes in the Equatorial Pacific, the United States first dredged out parts of the lagoon for a seaplane runway. But as seaplanes became obsolete, landing strips were built by U.S. Army engineers, one running east and west and the other north and south. Revetments, for the protection of fighter planes, also were built, and still remain. The east-west runway was extended and resurfaced by CAA in 1950. The north-south runway has since been abandoned as well as a fighter strip about three miles east of the main runway. The present runway is built to handle the largest commercial airliners now in use. It has a rotating beacon approximately forty feet above mean sea level with a split white light turning at 6 r.p.m. This has been reported as visible at distances of sixty miles by approaching planes, and thirty-six miles by surface vessels. It is lighted from dusk to dawn. The construction of this beacon makes Musick Light, a white cylindrical stone tower twenty-eight feet above the water on the south side of the lagoon entrance, less important. For some time it was lighted by request only. In 1954 it was maintained by the U. S. Coast Guard, and burned every night.

Musick Light was named in honor of Capt. Edwin C. Musick who inaugurated the first scheduled cargo and mail service between the United States and New Zealand on December 23, 1937. He and his crew perished off Samoa during the second flight in the following January. The plaque on the monument, erected in July 1938, reads as follows:

DEDICATED BY THE UNITED STATES
DEPARTMENT OF THE INTERIOR
TO THE CREW OF
PAN AMERICAN AIRWAYS
"SAMOAN CLIPPER"
LOST AT SEA ON JANUARY 11, 1938
WHILE SURVEYING FIRST SOUTH
PACIFIC AERIAL TRADE ROUTE

* * * * *

Captain E. C. Musick

C. G. Sellers	P. S. Brunk, Jr.
F. J. MacLean	J. W. Stickrod
J. A. Brooks	T. J. Findley

During the war pillboxes and other fortifications were erected, their cement remains still dotting the flat landscape. With the fall of Tarawa, Canton declined in military importance and in 1946 aviation facilities were transferred from the War Department to the Department of Commerce. In 1950, modern housing units for the CAA personnel were constructed near the runway on the northwest rim of the island. Plans are under way to consolidate all activities on the north side of the island. Pan American Airways, now renamed Pan American World Airways, and the British community are still on the south rim, as well as the quarters for American bachelor employees of CAA.

Canton Island gains its present importance from its strategic location. It is the fueling stop for three different commercial airlines, namely, Pan American World Airways, Qantas Empire Airways (QEA), and Canadian Pacific Airlines (CPA). These fly an aggregate of fifty passenger planes per month between Hawaii and Fiji. From these centers, as hubs, passengers can radiate by plane or boat to all parts of the earth. Canton Island has a wharf where vessels of 5,000 gross tons can tie up if necessary. It boasts two post offices in the very same building; one American, the other British. Postal service by air is available twice a week both north and south; by surface carrier at irregular intervals, averaging perhaps once in four to five months. Wireless service is available to the public. Being a center of air transport, installations are of the best. It has a modern weather bureau, employing seven men.

A hotel operated by PAA provides room and board at approximately $10.00 per day for transients. Moving the American population from the southside of the atoll to the northside has

gone apace. By 1954 CAA had ready for occupancy in the latter area 25 modern family quarters, had set up five quonsets, and had rehabilitated five former military quarters. PAA now has five family quarters; and Standard Oil, a two-family house there. A hospital, with a physician in constant attendance, is in the vicinity.

In 1951 there was no school for American children; but the few children of Gilbert and Ellice Islanders living in the British settlement were being taught by the fifteen year old daughter of the Chief of Police, a native of the Ellice Islands. By 1954, according to Evans, Canton "has a good school with a teacher furnished by the Department of the Interior, and a kindergarten-nursery school with a teacher hired by the residents. Twenty-six children attend the "grade" school, and twelve are in kindergarten. Three of the grade school pupils are Gilbertese - two girls and a boy. These Gilbertese children are bright. There is also a Gilbertese school in the British Compound."

Three oil companies do business on Canton. According to their announcements Asiatic Petroleum Corporation specializes in aviation gasoline and aircraft oils; Standard Oil Company of California, in Chevron aviation gasoline and R.P.M. aviation oil; and Standard-Vacuum Oil Company, in aviation gasoline 100/130 and Esso-aviation oil 120.

The only industry, not connected with air travel, is fishing. Three concerns are now licensed by the American and British governments to engage in this enterprise. Their catch is shipped by air to Honolulu. An impression of the relative importance of this business may be gained from the catch of one of the companies in July 1950. It removed a total weight of 17,984 pounds of fish from Canton, this amount breaking up into:

Mullet------	13,488	lbs.
Manini------	1,798	"
Aholehole---	1,079	"
Oio---------	899	"
Uu----------	719	"

The census of Canton Island, as of December 31, 1949 , is illuminating:

1. Population

Nationality	Men	Women	Children	Total
U. S. citizens	117	15	15	147
Gilbert and Ellice Islanders	106	15	13	134
New Zealanders	18	2	0	20
Fijians	12	0	0	12
Australians	8	0	0	8
Tongans	3	0	0	3
Part-Fijians	2	0	0	2
French	1	0	0	1
Total	267	32	28	327

2. Employer Organizations (employees only; dependents shown in totals above)

a. Fisher Associates
U. S. citizens----------32
Gilbert and Ellice Islanders------ 9
New Zealanders---------- 1

b. Pan American World Airways (estimated)
Gilbert and Ellice Islanders------66
New Zealanders----------15
Fijians----------12
Australians---------- 5
U. S. citizens---------- 4
Tongans----------3
Part-Fijians---------- 1
French---------- 1

c. Oil companies
U.S. citizens---------- 5
Gilbert and Ellice Islanders------ 5
Australians---------- 3

d. British Station
Gilbert and Ellice Islanders------16
New Zealanders---------- 1
Part-Fijians---------- 1

e. Private
Gilbertese---------- 1

(The 42 Fisher Associates personnel and the 5 U.S. citizens under Oil Companies are engaged in construction and do not represent "permanent" population, nor does the personnel of R.C.S. "Margaret", which vessel was in port on December 31, 1949.)

3. Federal Personnel
Civil Aeronautics Administration-----70
U.S. Weather Bureau---------- 7
U.S. Post Office Department---------- 1

The U.S. Government on Canton Island is administered like a ship at sea. The U.S..Administrator represents other government agencies in the following capacities: for example, for the CAA he is Island Manager; for Treasury he is Disbursing Agent/Cashier; for Justice he is Deputy Marshall; for Coast and Geodetic Survey he is Tide Observer.

(Of the 70 CAA employees shown, 25 are engaged in construction and do not represent "permanent" population.)

4. Traffic Data

Carrier	Weekly Flights	Passengers
Pan American World Airways	6	90
British Commonwealth Pacific Airlines	6	90
Canadian Pacific Airlines	1	15
U. S. Navy (Samoa)	1	15
Civil Aeronautics Administration	2/3	10
Weekly total	14 2/3	220
Annual total	762 2/3	11,440

(PAA has two weekly round trips from the U.S. mainland to Australia and one to New Zealand. BCPA has four round trips. CPA from Canada to Australia transits south one week and north the next. CAA aircraft fly from Oahu, Hawaiian Islands, to Canton Island and return approximately every three weeks. In 1954 Qantas Empire Airways replaced BCPA.)

5. Ships calling at Canton during the year

CAA----------9
Oil companies----------4
Gilbert and Ellice Islands Colony----3

The British Government on Canton is administered by the Colonial Office, and is in perfect harmony with the United States Administrator. British subjects are governed by British law; American citizens, by U.S. maritime law. Each nation respects the other's laws. It is forbidden under British law for Fijians and Gilbert and Ellice Islanders to drink intoxicating liquors; they have their harmless and refreshing kawa or yangona as a substitute. It is likewise forbidden for any British subject to supply any alcoholic drinks to such Pacific islanders, the punishment being imprisonment for three months or a fine of £50/0/0 or both. For an American, for example, to aid a British subject in breaking this British liquor law might subject him to dismissal from his position on the island as an undesirable troublemaker. For any heinous crime, on the other hand, the suspect would be tried in Federal court in Honolulu, Hawaii.

In this condominium, American workmen receive wages as high as or higher than workmen performing similar tasks in Hawaii or the continental United States. British workmen under British rule receive wages according to British standards. For instance, according to a regulation posted by the District Officer, June 14, 1950, the following wages for the employment of domestic colored labor were established as the legal rate:

Duties	Frequency	Rate per month
Washing and/or ironing	Once per week	$4.00
" "	Twice per week	7.00
General housework	Up to 3 hrs. per day (6 days per week)	12.00

"(Employers are not expected to maintain employees as regards rations, should they desire to do this, the District Officer will immediately be advised of this intention and will determine a reduction in the salary or salaries concerned, to meet such a contingency.)"

LAND FLORA

From the biological standpoint it is more logical to begin a discussion of a flora with the most primitive plants, aquatic ones, and to end with the most complex. But as the purpose of the visit to Canton dealt primarily with land plants, we shall begin our discussion with these.

According to a manuscript of Bryan's, who visited the island in 1924: "The rim varies in height from ten to twenty feet, and is for the most part covered only with low, prostrate vegetation, consisting of herbs and vines of common wide-spread Pacific species of Portulaca, Boerhaavia, Sesuvium, patches of Lepturus (bunch grass), Triumfetta, two species of Ipomoea, and stunted Sida bushes. A stretch of about two miles along the south side is covered with scaevola bushes, from 8 to 12 feet high. There are a few scattered Pemphis* bushes, a few Morinda, Tournefortia [Messerschmidia], and dry, scrubby Cordia trees. Most of the trees are scattered along the middle portion of the north rim; there are two patches near the N.W. point. Near the main lagoon entrance (on "Observation Point") are half a dozen coconut palms, the remnant of a number which were planted; and two other coconut palms are standing on the N.W. point. In 1937 the New Zealand solar eclipse expedition planted about 3,000 sprouted coconuts, some on the S.W. side and some on the N.E.; in time some of these may grow."

Before dealing briefly with the plant communities, each kind of plant observed or collected up to May 1951 is listed, with pertinent notes, below. These are arranged taxonomically. Numbers after the names of Fosberg and Walker refer to actual specimens collected in January or March 1949 and to be deposited in the U.S. National Herbarium in Washington. These have not been studied by the writers, but are here recorded on the basis of personal information submitted by F. R. Fosberg. Numbers after the names of Degener and/or Hatheway refer to specimens collected by these workers in 1950 or 1951 and deposited at the New York Botanical Garden, at the Bishop Museum in Honolulu, in the U. S. National Herbarium, and usually elsewhere.

Pandanaceae

Pandanus tectorius, the screwpine or hala, is native to the tropics but not to Canton. It is cultivated on the grounds of the PAA hotel on the southwest side of the island. The larger of

*Evidently in error for Suriana.

the two specimens is about ten feet high, picturesque and moderately healthy. Degener shipped seeds from Honolulu to Canton in July 1950. These germinated and are now planted out in the CAA housing area. They should thrive with perhaps a little watering during the driest seasons until their roots penetrate the sandy soil to depths allowing them to draw upon the layer of lighter brackish water which floats upon the heavier sea and lagoon water underlying every part of Canton's rim of land, and rises and falls with the tide.

Gramineae

Cenchrus echinatus (Fosberg & Walker 30,202, 30,217; Degener & Hatheway 21,252), the common sandbur, is a grass native to tropical America and obviously of recent accidental introduction. It was first recorded as collected on Canton in late 1949 or early 1950 by Katharine Luomala in her "Plants of Canton Island, Phoenix Islands", in Occas. Pap. B. P. Bishop Mus. 20 : 172, 1951. This, however, is not the first collection of the species as Fosberg & Walker had collected it January 30 - 31, 1949. It is ubiquitous about the airport and the civilized areas and still rare or wanting where man, carrying the burs on his socks, has not gone. It is an annual, springing up quickly during rainy weather, maturing its troublesome burs and then dying until the next rains come to wake the seeds into life.

Chloris inflata (D. & H. 21,251), a finger grass, was growing naturalized in a small patch in July 1950 near the abandoned runway. Seeds scattered by Degener about the same time had grown and matured by May 1951 in a thick stand near the wharf and oil tanks on the north side of the island, and near the hotel on the south side.

Cynodon dactylon (D. & H. 21,286), the Bermuda grass, is sparingly naturalized and carefully planted by residents near the hotel, at the airport and in the CAA housing area. According to Van Zwaluwenburg in the Haw. Pl. Record for 1941, this grass came to the island in importations of soil from Oahu. Seeds were also imported by a resident of the CAA housing area for planting in 1950.

Digitaria sanguinalis (D. & H. 21,315), a slender creeping grass, was found sparingly naturalized about the airport in July 1950.

Digitaria pacifica (Fosberg 30,886; D. & H. 21,316 -21,318) is the native annual bunchgrass known as D. stenotaphrodes to some authorities. It has fingered flower heads. It is found scattered here and there, preferably in recently disturbed areas such as along the sandy side of the road. It is a lush green, grows quickly after rains and usually dies shortly before the next rainy season. It is variable on Canton, requiring extensive study and probably segregating into several varieties. It has

been collected since early days. This grass is badly eaten by a grasshopper (Ailopus tamulus), accidentally introduced from perhaps Samoa or Tonga.

Digitaria timorensis (Hatheway 518) is an Oriental grass of accidental introduction growing in a few waste places near the hotel. It was first collected in February 1951.

Eleusine indica (F. & W. 30,211; D. & H. 21,254), the goosegrass, is native to the Old World. It is naturalized and very common only near human habitations. It is evidently of recent introduction, being first collected by Fosberg and Walker in January 1949. It is very successful because it is a quick-growing annual that can complete its life span during the short wet season.

Eragrostis amabilis (D. & H. 21,297), a pretty and delicate grass, is naturalized mainly about the hotel, and will undoubtedly extend its range. It is of recent accidental introduction.

Eragrostis whitneyi (F. & W. 30,206; D. & H. 21,319 and 21,320), very closely related and perhaps not specifically distinct from E. paupera, is a native grass first collected by Bryan in 1938. It is a pretty, dwarf, tufted annual growing on hard, sandy plains as, for example, near the airport.

Eragrostis pectinacea (D. & H. 21,312) is a very rare grass growing near the wharf on the north side. It is of recent accidental introduction.

Lepturus pilgerianus (D. & H. 21,291) is a very rare, native bunchgrass thus far known only from Canton, where it grew in sand. It is peculiar in being the only annual in the genus.

Lepturus repens (F. & W. 30,212; D. & H. 21,311) is a native perennial bunchgrass with columnar flower stalks. It has been collected since early times. It is somewhat variable. It is darker, harsher, denser and more abundant than the native Digitaria, and is tolerant of drier, more firmly packed areas. Its leaves are eaten by the introduced grasshopper. The terrestrial hermitcrab, described later, may kill certain tussocks by pulling out with the roots clawfuls of culms, starting these depredations from the outside of the cluster and gradually working toward the center. Perhaps their tender bases taste akin to corn on the cob.

Panicum miliaceum (D. &. H. 21,314) was found growing very localized near the hotel in 1950. It is of accidental introduction, perhaps derived from spilled canary bird seed.

Setaria verticillata (D. & H. 21,253), the bristly foxtail, is a nasty weed native to Europe. It is found everywhere near

habitations and is obviously of recent accidental introduction. The clusters of seeds adhere to clothing of all kinds. This grass is a successful annual, disappearing during the dry season.

Cyperaceae

Cyperus rotundus (Degener 21,413), the nutgrass, is a troublesome sedge of lawns and gardens throughout the tropics. It was one of the plants recorded by Van Zwaluwenburg in the Haw. Pl. Record for 1941 as imported in "soil from Oahu." Degener observed a few good stands in 1951 growing near the hotel but nowhere else.

Fimbristylis diphylla (D. & H. 21,288 and 21,289), a perennial sedge, grows near the outdoor theater. Because of its proximity to human structures or habitations, it is suspected to be foreign to Canton. It was probably accidentally introduced as seed from some other South Sea island, perhaps in a clod of earth stuck to machinery or to the shoe of some member of the Armed Forces.

Fimbristylis pycnocephala (D. & H. 21,290), another perennial sedge, grows on a barren plain near the CAA housing area. It forms harsh tussocks with pincushion-like flower-heads radiating in all directions. Because of its occurrence only in an area disturbed by man, it likewise is suspected to be a foreigner. This is probably the species recorded by Luomala as occurring on Canton in 1949 - 1950 (ibid. 168) and identified as F. cymosa.

Palmaceae

Cocos nucifera, the coconut. Not a single coconut palm is native to Canton. All were obviously planted. As mentioned above, Capt. Allen planted some coconut trees in 1916. Two, probably relics of that planting, grew for many years on the northwest point and were conspicuous and useful landmarks for ships at sea. They had become about 10 feet tall by 1924. The last survivor died in 1950, at a height of about 25 feet. In 1937 the New Zealand eclipse expedition set out about three thousand, but few survived. According to H. W. Bigelow in 1939, there were "nine scattered palms," and according to E. J. Witt in April of the same year also "many very small ones" about 18 inches high. There are some nice trees of medium size about the hotel, unfortunately infested by the Florida red scale insect (Chrysomphalus ficus), evidently due to the introduction of unfumigated plants. Small coconut palms are no longer rare elsewhere on the atoll, but grow only successfully where given a little care.

Araceae

Anthurium and Philodendron of several species were being grown as house plants in 1951, as well as a number of other

plants, belonging to various botanical families, which will probably never survive to become an element in the local flora. Many of these are purchased in flowershops in Australia, Fiji or Hawaii, carried in ladies' handbags on the planes, and then kept alive on Canton for a limited length of time. To list such casual and ephemeral introductions kept on bookcases and dining-room tables is hardly worthwhile.

Amaryllidaceae

Crinum asiaticum, the grand crinum, is native to the Orient. This hardy herb was introduced recently from Hull Island for planting about the hotel and the Terminal Building. The plants readily propagate from the base and become crowded. They then need thinning and replanting for best results.

Musaceae

Musa nana and other kinds of bananas have been imported from various regions and planted out. They persist with some care. It is recorded that some were set out in 1937 and later, but in July 1950 none was observed. By April 1951 new corms had been imported and were growing nicely where properly watered.

Casuarinaceae

Casuarina equisetifolia (Fosberg 30, 876; D. & H. 21,303), the horsetail beefwood or ironwood, is native to Australia and elsewhere in the South Seas. It is not native to Canton. Several trees are growing near the hotel, and are quite healthy. More should be introduced, even though no other plants, excepting perhaps the tree heliotrope, will grow beneath their falling branches, which simulate pine needles.

Casuarina glauca (Degener 21,372), the coarse ironwood tree, is likewise native to Australia and is foreign to Canton. It grows near the hotel, where it was planted many years ago. It is peculiar in sprouting from the roots at considerable distances from the main trunk.

Polygonaceae

Coccolobis uvifera (Fosberg 30,878), the seagrape, is native to the Bahamas. It is a densely leaved shrub or small tree planted and thriving about the hotel. The fruit is edible and can be made into jam and jelly. The plant was recorded by Van Zwaluwenburg in 1943 (Proc. Haw. Ent. Soc. 11. 3 : 306) as "recently introduced." The trees flower and fruit abundantly after rains, the seeds often germinating in the rainy season where they fall under the trees. These seedlings die for the most part during the prolonged drought. The annual supply of seeds from these trees, properly planted out, could soon markedly improve the entire aspect of the atoll. The plants are often

infested with the long-tailed mealybug (Pseudococcus adonidum), for the control of which an insect enemy can be introduced.

Amaranthaceae

Amaranthus dubius (D. & H. 21,295), an amaranth possible to use as a potherb in time of famine, now grows sparingly as an introduced weed near human habitations as, for example, about the hotel. It is a welcome addition to the island, which the spiny one, not yet here, would not be. Should the latter come, it should be eradicated before it has the opportunity to spread and become another prickly pest. An amaranth, species not given, was mentioned first by Van Zwaluwenburg in the Haw. Pl. Record for 1941 as reaching Canton in importations of soil from Oahu. Then in 1943 in the Proc. Haw. Ent. Soc., he refers to it again as "the recent immigrant Amaranthus."

Nyctaginaceae

Boerhavia tetrandra (F. & W. 30,207; D. & H. 21,305, 21,313), is a native perennial herb. It is found throughout the island, thriving everywhere excepting in the lowest, saltiest area. It has a few exceedingly long,fleshy, juicy roots at the surface of the ground to take advantage of the gentlest showers whose rainfall fails to penetrate the soil deeply. Its leaves are fleshy and its long-stalked flower clusters are white, not pink, as reported by some writers. The entire group is a difficult one. Some authors consider our plant to be B. diffusa, perhaps correctly so. It is subject to a native fungus disease (Albugo sp.) that dwarfs its leaves.

Aizoaceae

Sesuvium portulacastrum var. griseum (F. & W. 30,203 - 30,205; D. & H. 21,373; Degener 21,451) is a prostrate herb forming extensive mats of thick stems and leaves, preferably in depressions near the lagoon beach where salts may accumulate on drying. The plant is somewhat evil smelling. Being fleshy and rather brittle, it dies in solid black lines soon after the wheels of a car have passed over it. Its pale pink flowers are hunted out by the hermitcrab which, as in the case of the native purslane, eats stamens and ovary. In this case these crabs also extract the ripening seeds from the somewhat fleshy capsules for food. Perhaps in doing so, some escape, thus aiding the plant's dissemination. The plant readily roots at the nodes. The species itself has been recorded in error from the atoll by previous writers.

Portulacaceae

Portulaca lutea (F. & W. 30,208; D. & H. 21,285), the native

yellow portulaca or purslane, is a beautiful succulent, pale green perennial, resembling the jade plant. It grows everywhere. Its thick branches rise slightly from the ground. Its flowers open tardily in the morning and do not wilt until sunset or shade overtakes the plant. It can be eaten as a potherb in times of famine. The terrestrial hermitcrab feeds on the stamens and ovary, usually leaving the rest of the flowers attached to the plant.

Portulaca oleracea (Fosberg 30,881; D. & H. 21,283), the common purslane of Europe and America, is obviously of recent introduction. It may well have come from Hawaii to which Don Marin purposely introduced it in the early part of the nineteenth century. It is still of local distribution, growing mostly near human habitations. It is bound to spread and, from the appearance of a few plants, may be sparingly hybridizing with the native species. It differs from its native relative in being more prostrate, more slender, often somewhat red-stemmed, and in bearing smaller flowers opening usually in the morning and wilting at noon. It is used as a potherb, especially in France.

Cassythaceae

Cassytha filiformis (D. & H. 21,282), the love-vine, is native to Canton. It was first collected by Bryan in 1938. It is a rootless parasite consisting of pale green, intertwining string-like branches bearing tiny whitish flowers and marble-like fruits. Its sucking organs or haustoria rob other plants of sap. One love-vine may twine and gain nourishment from many different kinds of hosts. In one instance it was observed that one plant was growing on the native triumfetta alone, and thriving on this limited diet.

Leguminosae

Leucaena glauca (Fosberg 30,882; D. & H. 21,296), the haole koa of Hawaii, is a small tree with feathery leaves, pompons of small whiteeflowers and flat brown beans. It is native to tropical America. A few mature plants are in cultivation about the hotel, where they flower and sparingly reseed themselves. Van Zwaluwenburg stated in 1941 that the haole koa reached Canton in the importation of soil from Oahu. Thousands of seeds planted in April 1951 in many parts of the island appear to be tolerant of salt in the soil, and the seedlings are maintaining themselves in most cases where not exposed to extreme dryness.

Zygophyllaceae

Tribulus cistoides, the large-flowered caltrop or puncture vine, is typically a beach plant with flowers resembling a buttercup, and with nasty spiny fruits. These are a menace to barefoot bathers and may even puncture auto tires. This pretty weed was

recorded from Canton by Van Zwaluwenburg in the Haw. Pl. Record 45 : 17. 1941. It has not been observed by the writers who therefore consider the record erroneous.

Simaroubaceae

Suriana maritima (D. & H. 21,305), the baycedar, is native t coastal regions of both the Atlantic and the Pacific. It is a densely leafy shrub with small yellow flowers, and commonly grows gregariously. It is often used as a shelter by the ground-nesting tropic bird. This plant may have been mistaken for Pemphis by earlier writers.

Euphorbiaceae

Acalypha wilkesiana, the painted copperleaf, is a Fijian shrub now planted throughout the tropics as an ornamental hedge plant. A few specimens were observed cultivated in 1951 about the hotel. They were responding favorably to a little care and watering.

Chamaesyce hirta (Fosberg 30,873; D. & H. 21,298), the hairy-leaved spurge, is a low spreading herb with milky juice native to tropical America. It is a recent accidental introduction and grows well and often common in many areas influenced by man. It is a welcome addition to the ground cover of the island. More conservative botanists place this and the following two species in the genus Euphorbia.

Chamaesyce hypericifolia (F. & W. 30,216; D. & H. 21,300), the hypericum-leaved spurge, is related to the above. It is taller and is still rather rare, being known as yet only from the vicinities of the hotel and the airport.

Chamaesyce prostrata (D. & H. 21,299), the prostrate spurge, is another South American relative. It lies flat on the ground, has thread-like branches and tiny leaves. It is locally naturalized near the airfield, about the hotel and elsewhere but not away from the influence of man. This in itself proves its recent introduction. These three species may be the ones mentioned by Van Zwaluwenburg in 1941 as having come from Oahu in imported soil. The erect specimens collected by Luomala and recorded as E. prostrata were either parasitized by the fungus Nigredo proeminens or the specimens were misidentified.

"Euphorbia" (Fosberg 30, 214, 30,880), not seen by writers.

Euphorbia, see under Chamaesyce and Poinsettia.

Phyllanthus niruri, the niruri, a pantropic weed of American origin, was growing in 1951 in and about a box of soil imported from Fiji. It appeared to be spreading rapidly from seed to the surrounding area.

Poinsettia cyathophora (Fosberg 30,885; D. & H. year 1951) is sometimes called Euphorbia heterophylla var cyathophora. It is the fiddle-leaved poinsettia native to tropical America. Its upper leaves are basally blotched with bright red, adding color to the landscape. This erect herb is sparingly naturalized and protected in the spic and span British Settlement, where it grows on sun-scorched coral rubble that may act in part as a mulch to conserve ground moisture. It is of course a modest, wild relative of the garden poinsettia (P. pulcherrima), of which recently imported cuttings were being propagated in 1951 in cans by a resident of the CAA housing area.

Tiliaceae

Triumfetta procumbens (F. & W. 30,215; D. & H. 21,281), the trailing burbush, is native to Canton. It is a shrub with extremely long, trailing, woody branches and very long, spreading roots running just below the surface of the ground in all directions. It prefers arid dunes. The branches occasionally strike root five to six feet away from the mother plant, and from such centers additional trailing branches arise. The leaves are thick, roundish to slightly lobed, and bright green. The flowers are yellow and soon mature into spherical, spiny burs that lie in black masses where the mother plant may have eventually succumbed to an especially dry year. This plant could be mistaken for Tribulus.

Malvaceae

Hibiscus rosa-sinensis, the common hibiscus, is represented in gardens by less than a dozen plants.

Hibiscus tiliaceus, see under Pariti.

Pariti tiliaceum (Fosberg 30,888; D. & H. 21,284), the hau or vau of South Sea Islanders, is a relative of the hibiscus and by more conservative botanists placed in the same genus. It is a small tree with yellow flowers having a maroon center. These flowers fade reddish at night. In 1943 Van Zwaluwenburg reported insects "on the recently introduced 'hau'," thus giving us an approximate date as to the plant's coming to Canton. One slowly growing tree, suffering from drought, stands near the hotel laundry; a few others in neighboring gardens, and one at Musick Light. It produces flowers in spite of abuse. This tree, like many others introduced by Degener in 1950 for CAA, thrives when exposed to a little brackish water. A deep hole should have been dug for it through the coral rock and hardpan down to the water table. Into this hole a few posts or old boards should have been placed in an upright position before refilling with earth and planting the tree. The presence of the decaying boards would deter future formation of a troublesome hardpan and would facilitate root growth down toward water.

Sida carpinifolia, the hornbeam-leaved sida, is a native of tropical America but is now almost pantropic in distribution. It was represented in 1951 by a single wild plant growing near the hotel from a box of soil imported from Fiji.

Sida fallax (F. & W. 30,201; D. & H. 21,329), the ilima of the Hawaiian lei vendors, is a twiggy perennial shrub with finely velvety leaves and many small orange-yellow hibiscus-like flowers. It is native, and almost everywhere. For their dances, the South Sea islanders on Canton bedeck themselves with garlands made from this plant. The red-tailed tropic bird prefers to nest under its spreading canopy of branches and under the Suriana. Unlike the common ilima of Hawaii, whose flowers usually possess a dark eye, all flowers on Canton are uniformly colored. In studying thousands of plants, a few freaks or sports were observed. Should such plants become isolated on some island devoid of Sida otherwise and thus be prevented from cross-pollinating with more normal plants, they might develop into entirely new species or kinds. Such freak plants, therefore, are worthy of mention. One (D. & H. 21,330)possessed an unusually pale corolla; another (D. & H. 21,331), growing near the old guano diggings, bore filled flowers; and a third (D. & H. 21,332), growing near the CAA housing area, was densely twiggy and bore innumerable small leaves. These Sida, and the Scaevola as well, may be attacked by aphids. The ladybird beetle, Harmonia arcuata, however, tends to keep them under control.

Thespesia populnea (D. & H. 21,308), the milo of the Hawaiians, is a small tree with numerous leaves that can be eaten raw during times of famine. It bears an attractive hibiscus-like pale yellow flower with dark eye, and roundish corky seed pods that break open irregularly. Van Zwaluwenburg, at a meeting in May 1942 (published in the Proc. Haw. Ent. Soc. 11. 3 : 306.1943.), mentioned the occurrence of certain insects "On the introduced malvaceous tree 'milo'", thus proving that this species was on Canton previous to 1942, and even at that time was considered foreign to the native flora. In 1950 several trees were observed cultivated at the hotel and growing near the wharf on the north side of the island. This tree prefers access to brackish water.

Guttiferae

Calophyllum inophyllum, the true kamani of the Hawaiians, is native from India to the South Seas, exclusive of Canton. Where native, it grows to be a huge tree, bearing attractive white flowers and large round corky fruits from whose kernel a medicinal oil is expressed. The logs were used for canoes. A few trees were observed planted near the hotel. Their seemingly parallel-veined leaves were badly infested with the Florida red scale. Potted plants shipped to Canton by Degener in July 1950 and set out in the open were thriving in May 1951.

Tamaricaceae

Tamarix aphylla (Fosberg 30,877; D. & H. 21,306), the European tamarix, confusingly resembles the beefwood or ironwood. It bears, however, pink, heather-like flowers. Beautiful specimens have been planted on the hotel grounds. Cuttings from Oahu plants set out about some buildings in July 1950 were growing in April of the following year but were suffering from drought. They require a little watering and aid for their roots to penetrate the soil to greater depths.

Passifloraceae

Passiflora foetida, the foetid passionflower, native of tropical America, was observed in July 1950 growing carefully tended at the hotel and near the airport building. It is a recent introduction. Seeds planted in July 1950 by Degener did not germinate until after the unusual rains of April 1951.

Caricaceae

Carica papaya, the papaya, is native to tropical America and frequently grown locally from seeds derived from imported fruits. The seeds readily germinate and some of the resulting trees may grow to good size. Those observed are fruitless and invariably chlorotic, or yellowish. This is due either to the lack of some necessary mineral or more likely to the plant's inability to extract it from Canton, this soil perhaps holding it too firmly in some complex chemical bondage. Success might be gained by planting the seeds in a compost pit and adding a little solution recommended by local devotees of hydroponics. Reducing exposure to the intense sunlight might also be helpful in stimulating production of a crop.

Combretaceae

Terminalia catappa (Fosberg 30,875), the Indian almond, is native to the Old World. It is one of the few tropical trees that exhibits autumn coloration in its foliage. The kernel is edible and, rarely, the outer part of the fruit. It has been planted on the hotel grounds and would thrive excepting for insect injury. Seedlings, introduced in July 1950, were in a thriving condition the following May.

Terminalia samoensis (Fosberg 30,879), collected by Fosberg on March 6, 1949, was not collected by the writers. Nor did they notice T. melanocarpa or T. littoralis mentioned by Luomala.

Araliaceae

Polyscias guilfoylei, the panax of Hawaiian residents, was recorded in 1951 by Luomala as having been planted recently and

to have died later. It was noticed growing by Degener in the British Settlement in May 1951, but not thriving.

Apocynaceae

Ochrosia, species not determined, was observed in cultivation in 1950 on Canton by MacDaniels according to a personal communication.

Plumeria rubra (Degener, year 1951), the pink flowered frangipani, is native to tropical America. Several trees, cultivated in the hotel grounds living in July 1950 and covered with the crater scale, succumbed shortly after. Only one was surviving in May 1951. This scale insect is just another foreign pest that has been able to slip into the island for lack of proper regulations of inspection and fumigation. A few trees with small flowers from New Providence Island, Bahamas, where they are native and still growing wild, were set out in 1950 by Degener and are thriving.

Asclepiadaceae

Calotropis gigantea forma wilderi (D. & H. 21,294), the white crown flower, is a color form of the more common purple crown flower native to tropical Asia. It is commonly planted and grows well from cuttings. It, however, also suffers from chlorosis and its leaves may be eaten badly by caterpillars of the monarch butterfly, an insect occasionally flying here from over the ocean. The plant was recorded from the island for the year 1940 when Van Zwaluwenburg wrote about "the introduced Calotropis or 'crown flower'." Today a huge shrub grows near Musick Light, from which residents commonly gain cuttings.

Convolvulaceae

Calonyction species (D. & H. 21,309, 21,310), a moonflower, is obviously the second native morning glory recorded from Canton. It has been variously identified as Ipomoea grandiflora and I. tuba. It grows chiefly among arid guano deposits inland along the northeast rim. It is a climber bearing dark green, heart shaped leaves and large white flowers that bloom at night. By the time dry weather comes, it has matured its seeds and has died back to a massive rootstock. It is occasionally planted as an ornamental on trellises.

Ipomoea pes-caprae (Degener, year 1951), the beach morning glory, is practically pantropic, being limited in its extensive range, however, almost solely to sandy beaches. It was collected in 1924 by Bryan from "Canton Island, Obs. Point, lagoon side, small patch, el. ½ - 2 m. " and in 1938 on "west end, near camp, on sandy beach, alt. 2 - 3 m." Van Zwaluwenburg recorded it from Canton in the Haw. Pl. Record 45 : 17. 1941. Degener found an old flowerless plant with massive rootstock near the hotel

rubbish dump in April 1951. The plant grew inland near the remains of an army camp. No other mature plants are known to him. And as the cotyledons of seeds he planted in April 1951 were injured as soon as they appeared above the ground by land hermitcrabs, he suspects that the one old plant may have been planted by a soldier and partly guarded by him from injury until it had become established. The previously recorded plants, likewise, may have been protected by man. Because of the abundance of this creeper along tropical shores, new wave-borne introductions to Canton probably arrive from time to time and may persist until they succumb to the ravages of the crabs during some period of food scarcity.

Boraginaceae

Cordia sebestena (Fosberg 30,874; Degener 21,374), the geigertree, is native to Florida and the Bahamas. It is a small tree with sandpapery leaves, brilliant scarlet flowers, and whitish fruit. From the size of the trees about the hotel grounds, this ornamental must have been planted ten or so years ago. It suffers a bit from dryness, but more from leaf-eating insects and from scales. It fruits freely and some of the seeds germinate where they fall. These should be planted in new localities as this tree is worthy of more extensive cultivation on the island.

Cordia subcordata (Fosberg 30,887; D. & H. 21,287), the kou of the Hawaiians, has corky seeds adapted for dispersal by ocean currents. The kou may have reached Canton without human aid. If it did, it is interesting to speculate how many seeds reached the atoll before one finally escaped destruction by hermitcrabs and grew to maturity. Two small healthy patches of kou forest, occurring on the southwest end of the island have long been shown on maps and used as landmarks at sea. One of these interesting groves is unfortunately being damaged by picnic parties, some of whose members are apt to wield an ax indiscriminately. Other clusters of kou trees grow mainly near the old guano wharf, practically at the edge of the lagoon. These are said to have been planted years ago. Seeds from such trees should be collected for cultivation elsewhere on the island. The branches of the kou grow mostly erect, making them impossible nesting sites for clumsy nest builders like boobies and frigate birds. These branches bear large, pale leaves and nectar-filled orange flowers followed by the corky fruits enclosing several seeds. The trees near the lagoon are sickly, their branches often dying back to near the base during dry seasons and thus lending to the tropical landscape a wintry appearance. Death of the branches is hastened by land hermitcrabs which climb them to shred and eat the cripp, juicy bark on one side, usually the upper, for a considerable length. Though many fruits are produced to litter the ground under the trees year after year, only those that are fortunate enough to get buried can sprout their seed. The seedlings bear two dark green, longitudinally pleated cotyledons,

As the kou casts welcome shade about itself, it is always the resting place for hundreds of hermitcrabs. Some of these may wander about in the grove any time of day, while the majority sleep until the heat of the sun has waned and it is time to sally forth for food. Thus, every hour of the day, these seedlings are at the mercy of an army of voracious crabs. Though many seedlings appear above ground after a period of rainy weather, the writer has yet failed to see a single one escape annihilation. Obviously, seedlings arising from seeds transported away from crab-infested groves have a better chahce for survival. In spite of the destruction of seedlings, the groves often increase in size. This is accomplished mainly by suckering. The kou grows rapidly, seeds planted in July 1950 being erect trees a foot or more high by the following April. Trees are often badly defoliated, particularly on the lee side, by the caterpillars of a moth (Achaea janata), which prefers to lay its eggs on the side of the tree protected from the wind. About the only natural enemy this caterpillar has on Canton is a true, evil-smelling bug. This predator inserts its needle-like beak into its victim, sucking its juices and killing it. It is called Oechalia consocialis.

Messerschmidia argentea (Fosberg 30,884), the tree heliotrope, is the most beautiful tree on the island. It is incorrectly known as Tournefortia and "skayviola." It is native and most commonly forms clumps or small groves, a typical one persisting at the newly established plant nursery near the airport. It bears small white flowers and silvery leaves which, when dried, may be used as a substitute for tobacco. The leaves are often eaten by caterpillars of an ornamental moth (Utetheisa pulchelloides), but seldom seriously. Near the hotel one of the trees has become badly infested with the minute hibiscus snow scale (Pinnaspis strachani). As long as the tree is allowed to stand in this condition, it remains a menace as this insect may spread from it to all the tree heliotropes on the island. It reproduces rarely from seed, clumps increasing their size from shoots arising from reclining branches.

Solanaceae

Lycopersicon esculentum var. (D. & H. 21,307), the wild tomato, grows near the airport near the ruins of army shacks. It was observed first in July 1950 and, almost dead, again in April 1951. It is a sprawling plant with unusual leaves. It matches perfectly tomato plants growing wild in the Galapagos Islands and may prove to be an undescribed variety.

Nicotiana glauca (D. & H. 21,305), the tree tobacco, is native to the New World. It is a slender tree with bluish stems and leaves, and yellow flowers. A single plant was found in July 1950 near the CAA housing area. It was without flower and fruit, and had been badly mauled by a bulldozer. Seeds brought from Honolulu in July 1950 and sown among coral rock had flowered by April of the following year. The plants had been blown flat by the prevailing wind and were chlorotic. It is a very desirable introduction of great promise.

Physalis angulata (Degener 21,411), the husk tomato, is sparingly introduced, a few plants growing naturalized in the British Settlement in May 1951.

Rubiaceae

Morinda citrifolia (Degener 21,412), the noni of the Hawaiians, is native to Pacific Islands and can be readily transported by water from one region to another because of a special air chamber located at one side of the seed. If it were native to Canton, one should expect to find seedlings, but none was observed. Bryan in 1924 reported the noni as occurring "Single or in clumps." Degener found a single large tree, loaded with flowers and fruit, near the old guano wharf. Scores of hermitcrabs were resting in its shade, and not a single seedling anywhere. The seeds are probably eaten upon germination.

Cucurbitaceae

Cucumis melo, the muskmelon, was found growing near some abandoned shacks in July 1950. The seeds probably came to the island in a breakfast fruit.

Goodeniaceae

Scaevola frutescens (Fosberg 30,872; D. & H. 21,301, 21,302), known as naupaka in its Hawaiian variety sericea by the Hawaiians, is found in many varieties and forms along many coastal regions of the Pacific. Through local confusion, its name obviously has been transferred to Messerschmidia as "skaviola." The plant native to Canton is a shrub eight or more feet high bearing large shiny smooth leaves, and white flowers and fruits. It grows gregariously. It is extremely important as, from time immemorial, its extensive groves were preferred as rookeries by boobies and frigate birds. The accumulation of their excrement, century by century, built up the guano deposits for which Canton first gained commercial recognition. Being gregarious, these birds avoid isolated naupaka bushes and instead nest in those growing in dense groves. Isolated bushes and groups of young bushes too small for nesting sites are usually a beautiful, crowded mass of healthy green leaves and white flowers and fruits. Bushes in the rookeries, in contrast, are sickly, dying or dead.

This unfavorable condition of the naupaka in the rookeries is not due so much to mechanical injury caused by the heavy birds clumsily alighting among the branches, as to the chemical action of the bird droppings. The details of these chains of chemical reactions, especially in a calcareous soil impregnated with sea salt, still remain to be worked out. Nevertheless, we are reasonably sure that two types of injury occur: first, the excrement of birds, rich in uric acid, is splattered wet over the leaves, in part absorbed by them, variously modified into other poisonous substances, and then translocated throughout the plant to its great detriment; second, much fresh excrement litters the ground. To this mass are added the whitewashed dying leaves as they fall or, in case of rare, cleansing showers, their

coating of filth. Simply explained, the naupaka in Canton rookeries are very like garden plants dying from an excess application of chicken manure. They just can't tolerate these various nitrogenous compounds in such concentrated form.

As a result of this interaction between nesting birds and plants, there appears to exist something of a cycle, not clear cut, to be sure. Under simplified, ideal conditions it might best be explained as consisting of flocks of birds gradually killing with their excrement a grove of naupaka bushes in one area. While this is transpiring, seedlings of naupaka are growing healthily elsewhere undisturbed by nesting birds. As the old poisoned bushes finally succumb and break to the ground, the birds, somewhat unwillingly at first, are forced to shift their rookeries to the stands of naupaka which by this time have grown sufficiently tall and sturdy for nesting sites. The cycle then repeats itself as these plants, in turn, gradually succumb to poisoning and crumble away, obliging the birds to shift to still another stand of young bushes, probably actually growing in a locale where their ancestors had been killed out several hundred or thousand years before. Test holes dug by Hatheway show deposits of guano where no shrubs now exist. We cannot imagine that the ancestors of our present guano-producing birds had radically different nesting habits from the present generation. The presence of guano almost certainly indicates the former presence of groves of vegetation.

Compositae

Emilia sonchifolia, the purple emilia, was not observed by the writers in 1950-51. But Van Zwaluwenburg in the Haw. Pl. Record for 1941 stated that "Importations of soil from Oahu have resulted in the recent establishment on Canton of several weeds such as Emilia sonchifolia. . ."

Pluchea odorata (F. & W. 30,210; D. & H. 21,295), the shrubby fleabane, is native from Florida to northern South America. It is naturalized here and there about the airfield and disturbed areas, and is evidently of recent accidental introduction. It is expected to extend its range.

* * *

Thus far, individual kinds of plants have been discussed. Now we shall deal briefly with associations* of plants.

Portulaca lutea and Boerhavia grow together, with the exclusion of every other kind of plant, in large areas of consolidated reef and rubble. When even slight showers fall, their shallow roots can absorb the rain, and this water is stored in their tissues for use during long periods of drought. In other places the rootless Cassytha likewise occurs, parasitic on the two plants. Where the soil is more sandy, Portulaca and Boerhavia may be associated with the perennial bunchgrass Lepturus. In general, Portulaca and Boerhavia are the two commonest native plants on Canton, growing almost everywhere,

* A more technical paper, with statistics, on plant communities is presented by Hatheway as Atoll Research Bulletin 43.

associated with practically every other plant excepting with Messerschmidia, Scaevola and kou. The reason is not that these three shrubs and trees are poisonous, like the Eucalyptus and Casuarina to other plants, but that they cast too much shade for these sun-loving herbs to tolerate.

Another close community, since historic times, grows only near the influence of man and consists of the annuals Cenchrus, Eleusine and Setaria; Cenchrus being the most abundant and, because of its prickly burs, the most annoying.

Suriana often grows alone in slab areas and less often in sandy areas swept by waves during violent storms. In 1951 many of the largest plants were dead, leaving fantastically gnarled branches and twigs reaching toward the sky. The frigate bird often roosts upon the sturdier branches but does not nest among them.

The native annual varieties of Digitaria often grow alone, preferably in recently disturbed sandy soil, as along the shoulders of roads. They require more moisture than Lepturus repens and can survive from year to year on Canton by having speeded up their life cycle. Being unable to survive periods of drought as growing plants, they survive them in the form of seed lying dormant on the ground.

A plant that occurs mostly amid rock slabs or on sand dunes nearest the ocean breakers is Triumfetta. This perennial creeping shrub has incredibly long, shallow roots able to absorb rain from gentle showers, and thick leaves with water storage tissues.

Scaevola grows gregariously mostly on the southeast, or windward, part of the atoll rim, perhaps because the rainfall there is slightly more than on the lee side of the island. A few isolated bushes occur across the lagoon on the opposite side, the corky fruits having been blown across the surface of the lagoon to that shore by the prevailing wind. Sporadic plants grow in a few other places as well.

The kou, probably due to the influence of man, is most abundant along the lagoon side near the old guano diggings. The plants grow alone or perhaps with a few Messerschmidia interspersed.

Sida, a sun-loving shrub, grows preferably in good sandy soil in association with any plants that do not subject it to shade.

The Sesuvium is most tolerant of salt and consequently grows alone; other kinds of plants cannot survive in low areas that are inundated by the lagoon. During dry weather and exceptionally low tides the ground where it grows glitters with salt crystals.

The native land flora of Canton Island, excluding the kou and the beach morning glory as plants of questionable nativity, comprises only fourteen kinds of flowering plants. Not a single fern, moss nor slime-mold is native. How many fungi and terrestrial true algae and blue-green algae occur is not yet known. There are quite a number to be found in unexpected places, as in the turbo shells carried about by the hermitcrabs on land. Due to commerce, the common molds found on foodstuffs have reached Canton. There are doubtless numbers of native fungi yet to be discovered, especially after spells of wet weather. Thus far a powdery mildew was collected by Degener on the native Sida; an Albugo on the leaves of Boerhavia; and a saprophytic, dirty yellow ascomycete, about 1 cm. wide, on introduced rubbish.

The paucity of native land plants on Canton is due to the scarcity of rain and its unfavorable distribution during the year, to the salty or nitrogen- and phosphates-impregnated character of the barren soil, to the low elevation enabling waves during storms and very rare tsunamis or tidal waves to scour the atoll bare of most life, and to the army of omnivorous hermitcrabs. Canton is not so isolated that seeds and other propagules of land plants cannot reach its shores. Almost all such castaways evidently find conditions too unfavorable for survival.

Even though Canton is unfavorable for the growth of plants, similarly arid, salty or chemically-poisoned regions throughout the world have been successfully invaded by various rugged plant pioneers. Some are peculiar to the Mojave and other alkali deserts in America; some to the calcareous soils of Florida, the Bahamas or Dalmatia; some to the Sahara; to Madagascar; to India; to Australia and the South Seas; or to the leeward sides of the Hawaiian Islands; etc. To cover Canton with a mantle of vegetation, however, is more than just selecting seeds of such pioneer species and sowing over the rim of the atoll. As a fundamental practice, seeds of potentially poisonous plants, such as those of the yellow oleander (Thevetia peruviana), or of thorny plants, such as the klu (Vachellia farnesiana) and algaroba (Prosopis chilensis), have been omitted. The following is a list of plants or seeds, with their native home, shipped by the writer to Canton chiefly in 1950. All were properly fumigated by the Board of Agriculture and Forestry, Honolulu, to guard against the danger of introducing insect pests. Some seeds of plants that should be able to grow on Canton could be supplied in only small quantities due to their extreme rarety. Others, of plants that probably will not grow there, were sent anyway because of their availability without extra cost or labor. After all, some of these may germinate and grow in particularly sheltered places. Only after these plants have actually become naturalized will it be worthwhile describing them in a supplement to the present paper.

Species sent to Canton in 1950, unless other date given, and place of origin:

MARSILEACEAE
Marsilea villosa - Hawaii

GRAMINEAE
Dactyloctenium aegyptium - Egypt
Digitaria henryi - Formosa
Echinochloa colonum - Pantropic
Ischaemum brachyatherum - Africa
Lagurus ovatus - Yugoslavia (1953)
Panicum cinereum - Hawaii
Panicum nubigena - Hawaii
Panicum pellitum - Hawaii
Pennisetum sp.
Polypogon monspeliensis - Europe
Sporobolus virginicus - Southern United States
Tricholaena repens - Africa

CYPERACEAE
Cyperus javanicus - Hawaii
Cyperus trachysanthus - Hawaii
Fimbrystylis cymosa - Hawaii

PALMAE
Phoenix dactylifera - Africa
Pritchardia pacifica- Fiji
Pritchardia sps. - Hawaii

COMMELINACEAE
Commelina benghalensis - India
Rhoeo discolor - Bahamas

LILIACEAE
Sansevieria cylindrica - Africa
Sansevieria guineensis - Africa

AMARYLLIDACEAE
Furcraea gigantea - America

SANTALACEAE
Santalum ellipticum - Hawaii

POLYGONACEAE
Antigonon leptopus - Mexico
Coccolobis uvifera - Bahamas

CHENOPODIACEAE
Atriplex angulata - Australia
Atriplex halimoides
Atriplex semibaccata - Australia
Chenopodium oahuense - Hawaii
Kochia sp. - Australia

NYCTAGINACEAE
Mirabilis jalapa - Mexico

AIZOACEAE
Dorotheanthus criniflorus - Africa
Tetragonia expansa - New Zealand

PORTULACACEAE
Portulaca cyanosperma - Hawaii

PAPAVERACEAE
Argemone glauca - Hawaii

CAPPARIDACEAE
Capparis sandwichiana - Hawaii

CRUCIFERAE
Coronopus didymus - Europe
Lepidium o-waihiense - Hawaii

CRASSULACEAE
Kalanchoe tubiflora - Africa

LEGUMINOSAE
Acacia choriophylla - Bahamas
Desmanthus virgatus - Tropical America
Chamaecrista leschenaultiana - India
Dolichos lablab - Africa
Erythrina sandwicensis - Hawaii
Indigofera suffruticosa - West Indies
Medicago hispida - Asia
Medicago lupulina - Asia
Phaseolus lathyroides - Tropical America
Phaseolus trilobus - Asia
Sesbania tomentosa - Hawaii
Sophora tomentosa - South Seas
Tephrosia purpurea - Hawaii
Vigna marina - Hawaii

ZYGOPHYLLACEAE
Guaiacum officinale - Bahamas

MELIACEAE
Melia azedarach - India

SAPINDACEAE
Sapindus oahuensis - Hawaii

RHAMNACEAE
Colubrina asiatica - Hawaii

MALVACEAE
Abutilon mollissimum var. sandwicense - Hawaii
Gossypium brasiliense - South America
Gossypium tomentosum - Hawaii
Pariti tiliaceum - South Seas
Sida fallax - Hawaii
Thespesia populnea - Hawaii

STERCULIACEAE
Heritiera littoralis - South Seas
Waltheria americana - Hawaii

GUTTIFERAE
Calophyllum inophyllum - Hawaii

TAMARICACEAE
Tamarix aphylla - Asia

PASSIFLORACEAE
Passiflora foetida - Bahamas

CARICACEAE
Carica papaya - Tropical America

PUNICACEAE
Punica granatum - Mediterranean

LECYTHIDACEAE
Barringtonia asiatica - India

RHIZOPHORACEAE
Bruguiera sexangula - Malaya
Rhizophora mangle - Tropical America

COMBRETACEAE
Conocarpus erectus - Bahamas
Terminalia catappa - Malaya

PLUMBAGINACEAE
Plumbago zeylanica - Hawaii

OLEACEAE
Noronhia emarginata - Madagascar

GENTIANACEAE
Centaurium sebaeoides - Hawaii

APOCYNACEAE
Plumeria rubra - Tropical America

ASCLEPIADACEAE
Calotropis gigantea - Egypt

CONVOLVULACEAE
Ipomoea cairica - Egypt
Ipomoea cordofans - Africa
Ipomoea indica - Hawaii
Ipomoea japonica - Japan
Ipomoea pes-caprae - Hawaii
Ipomoea triloba - America
Jacquemontia sandwicensis - Hawaii
Operculina aegyptia - Egypt

BORAGINACEAE
Cordia subcordata - Hawaii
Heliotropium anchusaefolium - South America
Heliotropium curassavicum - Hawaii

VERBENACEAE
Stachytarpheta jamaicensis - Bahamas
Stachytarpheta urticaefolia - South America
Vitex trifolia var. simplicifolia - Hawaii

LABIATAE
Leonurus sibiricus - Asia
Marrubium vulgare - Asia
Ocimum gratissimum - India
Phloemis fruticosa - Yugoslavia (1953)
Plectranthus australis - Hawaii
Salvia coccinea - Mexico

SOLANACEAE
Capsicum frutescens - Tropical America
Lycium sandwicense - Hawaii
Lycopersicon esculentum var. galeni - South America
Nicandra physalodes - South America
Solanum nigrum - Hawaii

ACANTHACEAE
Asystasia gangetica - India

MYOPORACEAE
Myoporum sandwicense - Hawaii

RUBIACEAE
Canthium odoratum - Hawaii
Casasia clusiifolia- Bahamas
Morinda citrifolia var. Potteri - Fiji

CUCURBITACEAE
Citrullus vulgaris - Africa
Cucumis dipsaceus - Arabia
Momordica charantia var. abbreviata - Asia
Sicyos microcarpus - Hawaii

GOODENIACEAE
Scaevola frutescens var. sericea - Hawaii

COMPOSITAE
Bidens amplectens - Hawaii
Borrichia sp.
Eclipta alba - Asia
Gaillardia picta - Texas
Helianthus annuus - Kansas
Heterotheca grandiflora - California
Inula candida - Yugoslavia (1953)
Lipochaeta integrifolia - Hawaii
Lipochaeta remyi - Hawaii
Pluchea indica - India
Reichardia picroides - Southern Europe
Sonchus cornutus - Africa

After Degener with his efficient assistant returned to Hawaii from a week's stay on Canton in July 1950, he never expected to see the atoll again. From Honolulu, as per contract, he shipped the proper seeds, some in enormous quantities, and a few kinds of living plants, by CAA plane to their destination. Numerous residents of Canton, all busy with their professional duties, tried to sow the seeds during their spare time and even watered some choice plants with precious distilled water. But the task was so Herculean that the greater part of the shipments simply reposed in a warehouse, slowly deteriorating.

On the invitation of CAA for transportation and lodging, and PAA for meals, Degener volunteered his services for six weeks to bring the project to a successful close. Back on Canton in April 1951, he noticed numerous damselflies near the airport. Knowing these pretty, delicate insects to be aquatic in the larval stage, their presence proved the existence of fresh, or nearly, fresh water - SOMEWHERE!

The source was soon found - a rectangular body of water about 20 by 50 feet, and 3 to 4 feet deep. The site may have been excavated by some branch of the Armed Forces as an emergency source of water to fight conflagrations during the war. The sides were of wooden beams; the bottom, natural coral sand and rubble. The location, near a grove of "skayviolas" (Messerschmidia) not far from the airport, was ideal. It lay near the center of a wide part of the atoll's rim, just about right to take advantage of the so-called Ghyben-Herzberg lens.

Disturbing factors absent, this double-convex lens consists of a body of fresh ground water, originally derived from Canton rain, floating on top of the heavier sea water that has percolated under it from the ocean since prehistoric times (See Arnow, T., 1954, "The Hydrology of the Northern Marshall Islands"; Atoll Research Bull. 30, May.). Here, then, was a never failing source

of water that barely tasted salty, regularly rising and falling with the tide, though with a certain lag in time, and in height and depth. With the help of a gang of Gilbert and Ellice Islanders under the kinky-haired Melanesian Seitoa, a wooden platform was built so that the fluctuation in water level would alternately cover it a few inches and then leave it exposed to drying. With such labor, it took little time to gather from a neighboring kitchen midden thousands of discarded tins, stab holes in them, fill them with the best earth available, and then plant seeds of the more ornamental plants therein. Many of the species shipped to Canton, as study of the accompanying list shows, are more or less halophytic - salt-loving or at least salt-tolerant. Naturally they throve, irrigated by every tide with an abundant supply of near-sweet water. By the time Degener left the atoll in May 1951, this self-watering nursery was green with seedlings of many kinds, available for any one who wished to plant them about their barren, arid grounds. Many of these plants survived transplanting, particularly when occasionally watered with waste from the dishpan or bath.

The great majority of the seeds, particularly of grasses, were scattered, hit or miss, over the atoll in likely places. Others were planted in holes made in the sand and rubble with the human heel or with the spade. To ascertain what species on Canton can survive and maintain themselves from year to year in spite of drought, salt, intense sunlight, insects, sea birds, voracious hermitcrabs and competition with other plants, will be of considerable importance not only to tiny Canton but to similar islands throughout the world. The Canton project will help show workers elsewhere what activities to repeat or modify and what pitfalls to avoid.

AQUATIC FLORA

A discussion of the aquatic flora and fauna hardly concerns the present immediate problem of augmenting the flimsy mantle of vegetation on Canton's arid rim of land. Yet were it not for the aquatic flora and fauna, Canton Island would not even be in existence. It consists almost entirely of the accumulated remains of coral, mollusk, sea urchin and star fish, coralline alga, pink foraminifera shell, and the droppings of sea birds that have eaten free- swimming organisms of the open ocean as food. The terrestrial hermitcrabs that are such a hazard to the land plants are aquatic in their larval stage. So with the importance of the sea life in mind, the reader will perhaps excuse a continuation of this article about Canton. It will be brief, not purposely, but because of our present ignorance. This state of affairs should stimulate the resident having a flair for biology to spend some of his spare time collecting the yet unknown plants and animals of Canton to ship to eager specialists at the Bishop Museum and elsewhere for technical study. The

amateur collector and careful observer on Canton, collaborating with the museum expert surrounded by his musty books and pickled specimens thousands of miles distant, can solve so many fascinating and important puzzles. As such knowledge accumulates, a more complete article than the present one can be written for later readers. This one is but a beginning and barely scratches the surface.

Of blue-green algae, no one had collected any specimens previous to 1951, thus leaving practically an open field for a local resident in pursuit of an important hobby. The three specimens collected that year were actually found on land, but are being classified as aquatic because they developed mainly during an unusual period of rainy weather or were found in ditches occasionally subject to flooding by rain or tidal seepage. They are hardly land plants. Though microscopic, such plants, because of their enormous numbers, may help bind sand grains together and reduce drifting. This action may be mechanical, by means of the gelatinous plant surface, as well as chemical, by the liberation of carbon dioxide and the partial dissolving of the calcareous sand grains followed by cementation.

Microcoleus paludosus (Degener 21,341) forms a tough gelatinous coating over the surface of the sand on the atoll rim during periods of rainy weather. Of the blue-green algae on Canton it is the most useful sand binder.

Porphyrosiphon sp. (Degener 21,338) grows on or in the sand during periods of rainy weather but does not form a gelatinous coating. It is similarly useful, but to a lesser degree.

Scytonema hofmannii (Degener 21,347), like the previous two species, is dormant during dry weather. Soon after the coming of rain, it reproduces prodigiously, often washing into puddles in loosely flocculent masses to stain them a pale olive green.

A blue-green alga, not yet identified, is paradoxically beautifully pink. It imparts its color to extensive areas of drying salt flats near the narrow end of the atoll, occurring among crystals of sea salt.

Of the green, brown and red algae, commonly known as seaweeds, we likewise know very, very little so far as Canton is concerned. Some are important reef builders while others constitute the fundamental and first link in the complicated food chain terminating, we like to believe, in serving the highest type of organism, man, at the dinner table and elsewhere. It is an old story known to most of us but worth repeating.

These plants, bathed by sea water, actually a nutrient solution or nourishing soup to them, vary in size from the microscopic to about a foot in length, like the Turbinaria and the

Sargassum that are cast ashore so often. Employing sunlight as a source of energy - an activity not ordinarily possible to members of the Animal Kingdom - they manufacture sugar, starch and allied products for the purpose of growth and activity. Minute and often humble animals like worms, mollusks and crustaceans browse upon these algae for food. These animals in turn usually end up as food for larger and ever larger kinds until we realize that our economic fishes, sea birds, seals and even whales are, in a sense, simply reincarnations on a higher plane of the energy of algae originally trapped from the sun.

If conditions for the growth and abundance of algae are favorable, as along the Humboldt Current of South America, the surrounding water and air just teem with valuable fish and sea bird life. If conditions for algae are unfavorable, however, fish and bird life are scant, and our dining table may be missing a fish course and, as lack of guano fertilizer makes farming expensive, an extra vegetable or a salad. Thus the fluctuation in the growth and abundance of algal life in the ocean may affect man most intimately.

The first true alga collected on Canton may be Turbinaria ornata (F. & W. 30,213), gathered by Fosberg and Walker January 30 - 31, 1949. Subsequent collections, made mostly by Degener in abundance in 1951 and eventually to be deposited in the herbaria of the New York Botanical Garden, the Bishop Museum and elsewhere, were turned over to Dr. Maxwell Doty and kindly identified by him as follows:

CHLOROPHYTA

Ulvaceae

Enteromorpha sp. (Degener 23,660)
Ulva lactuca ? (Degener 23,661)

Cladophoraceae

Cladophora sp. (Degener 23,662)
Cladophoropsis membranacea (Degener 23,663)

Caulerpaceae

Caulerpa crassifolia (Degener 23,664)
Caulerpa peltata (Degener 23,665)
Caulerpa serrulata (Degener 23,666)

Valoniaceae

Dictyosphaeria cavernosa (Degener 23,667)
Valonia sp. (Degener 23,668)

PHAEOPHYTA

Fucaceae

Turbinaria ornata (Degener 23,669)

RHODOPHYTA

Gelidiaceae

Gelidium sp. (Degener 23,670)

Gigartinaceae

Ahnfeltia concinna (Degener 23,671)

Sphaerococcaceae

Gracilaria lichenoides ? (Degener 23,672)
Hypnea spinella (Degener 23,673)

Rhodomelaceae

Chondria sp. (Degener 23,674)
Herposiphonia tenella (Degener 23,675)

Ceramiaceae

Centroceras clavulatum (Degener 23,676)
Ceramium sp. (Degener 23,677)

Grateloupiaceae

Halymenia sp. (Degener 23,678)

Corallinaceae

Jania capillacea (Degener 23,679)
Lithothamnion sp. (Degener 23,680)

Among diatoms, a species of Navicula (Degener 21,337) was collected.

AQUATIC FAUNA

No worms seem to have been recorded from Canton thus far. Degener in 1951 observed some wide, colorful planarians, and under rocks on the ocean reef worms (Eurythoe pacifica) armed with stinging bristles; and earthworm-like worms in the fine sand of shallow areas of the lagoon. Lack of proper equipment, unfortunately, made their collecting impracticable at the time.

Apparently the first starfish ever collected was Linckia multifora (No. 271) by Bryan in 1925. Degener collected L. diplax (No. 1205) and a serpent star (No. 1206) twenty-six years later on the ocean reef. He of course observed sea urchins. Their spines can inflict dangerous wounds. Corals and sponges are everywhere, yet remain to be collected and studied. These can cause scratches and abrasions that at first sight appear trivial yet may cause stubborn ulcers. Application of a poultice wet with a solution of epsom salt to such wounds is a useful home remedy that may forestall the need of visiting a physician later. Mollusks are probably the best known of the marine animals native to the atoll. Though somewhat disappointing in form and coloration for what one would ordinarily expect on a tropic island, they are so easy to preserve that most people wandering along the shore gather them in a casual way. There have been some serious amateur collectors whose finds may have reached museums for determinations, but where is not presently known. Determination of the mollusks, collected chiefly by Degener, was begun by Dr. Louis Brand of Cincinnati and continued by Mr. A. Wray Harris of Honolulu. Due to the latter's untimely death on December 17,1953, the complete list of Canton mollusks will appear as a supplement in the Hawaiian Shell News. The shipworms presently known from the atoll are:

Teredo samoaensis (R. S. Danner), 1941.
Teredo gregoryi (Van Zwaluwenburg), 1941.
Teredo bensoni (C. H. Edmondson), 1940 (?). This new species of shipworm was discovered in the "dredger Benson on its return to Honolulu after completing operations at Canton Island."

Nonmicroscopic crustaceans are abundant in species where coral or other kinds of rocky marine shelves and shores exist. There they find suitable shelter and food. The unusually salty lagoon of Canton with its barren sand and choking calcareous mud, particularly distant from the channel, is like a desertton land, able to support but little life. But the collector who can search the steep ocean bottom about Canton's rim from a depth of about 25 fathoms to the limit of high water will be rewarded with innumerable species never before recorded. Thus far the only crustaceans known to the writers from Canton, mostly from the ocean side, are the following: They were identified for the most part by Dr. C. H. Edmondson. Due to an oversight, original ecological data on the labels were discarded in transferring the specimens to permanent museum jars for preservation.

Limnoriidae

Limnoria multipunctata (U.S.N. Survey 5734), 1950. An isopod destructive to wood exposed to sea water, by excavating small burrows in it.

Palaemonidae

Anchistus miersi (Degener), 1951.

Stenopodidae

Gonodactylus sp. (Degener 5658), 1951.

Pontoniidae

Conchodytes meleagrinae (Degener 5685), 1951. A shrimp living in the mantle of the tridacna.

Coenobitidae

Coenobita perlatus (Degener 5661, 5662), 1951. The ubiquitous land hermitcrab; listed by Luomala in 1951 as C. olivieri.

Paguridae

Calcinus elegans (Degener 5665), 1951. A hermitcrab with orange markings.

Calcinus elegans var. (Degener 5669). The blue variety of the above; more abundant.

Calcinus herbstii (Degener 5666 - 5668), 1951. A hermitcrab, brown and white.

Clibinarius corallinus (Degener, 5670, 5671), 1951.

Porcellanidae

Pachycheles pisoides ? (Degener 5684), 1951. Not a typical crab though like one in appearance.

Inachidae (Majidae)

Micippa patypes (Degener 5667), 1951.

Portunidae

Thalamita picta (Degener 5682), 1951. A very active crab, running as well as swimming.

Xanthidae

Actaea sp. (Degener 5675), 1951.

Carpilodes bellus (Pan American World Airways 5449), 1949.

Chlorodopsis scabricula (Bryan 2386), 1924.

Chlorodposis areolata (Degener 5677), 1951. Common; legs hairy.

Eriphia scabricula (Degener 5678), 1951.

Eriphia laevimana (Degener 5672), 1951.

Leptodius sanguineus (Degener 5679), 1951.

Phymodius ungulatus (Degener 5683), 1951.

Polydectus cupulifer (Degener 5663), 1951. Crab carrying sea anemones.

Grapsidae

Geograpsus grayi (Degener 5681), 1951.

Metopograpsus messor (Degener 5680), 1951. Crab of mud and rocks, often going into brackish water.

Pachygrapsus minutus (Degener 5676), 1951. Crab of mud and rocks of lagoon shore and often crawling onto land.

Percnon planissimum (Degener 5664), 1951. Very active crab walking upside down on under side of flat rocks along reef.

Ocypodidae

Ocypode ceratophthalma (Degener 5659), 1951.

Lepadidae

Lepas anatifera (Van Zwaluwenburg 302), 1941. A goose barnacle.

Scalpellidae

Lithotrya pacifica (Degener 386), 1951. A stalked barnacle on reef exposed at low tide.

Fishes are plentiful and colorful. Casual observation of reef fishes of Canton by one familiar with those of Hawaii will reveal a high proportion of species common to both areas. Yet, usually a subtle difference is observable perhaps in color, shape or activity, differences lost upon death and preservation for later study in a museum. Too, food fishes that are wholesome in Hawaiian waters and elsewhere may be poisonous in Canton, especially if caught in the lagoon. Savory looking red snapper and rock cod are usually poisonous to eat. Such fish when eaten may cause paralysis, at times severe enough to endanger life unless the prompt aid of a physician is sought. This fact suggests that plant or microscopic animal life, the source of fish food, is fundamentally responsible. This problem presently is being investigated by Dr. S. Gregory Ross and a very few other pioneer workers. Sharks, sting rays and moray eels are common in the lagoon, making bathing exciting if not dangerous. Of course, all these creatures, when caught by birds, may add to form guano deposits of the future. Fishes of Canton are studied in Schultz' Fishes of the Phoenix and Samoan Islands collected in 1939 during the expedition of the U.S.S."Bushnell," Bull. U.S.N.M.180:1943.

Except for this the scientific study of the fishes of Canton is still in a preliminary stage. The first fishes collected for serious study appear to be Eviota viridis (E. H. Bryan, Jr.,4819) and Echeneis remora (Bryan 4895) in March 1924.

Land Fauna

The land fauna of Canton is meagre. The only wild mammal noticed was a single rat which ran with a strange jogging gait across the road at night before the car. It lost itself in a maze of trunks and twigs of a frigate bird rookery of scaevola bushes far from human habitations. It was the Polynesian rat whose ancestors may have reached the atoll in the double canoe of some adventurous Polynesian centuries ago, or perhaps on a larger vessel during the later guano digging days. It is not unlikely that the kou reached the island on the same canoe or vessel with the Polynesian rat. Besides man, of all possible ethnological strains imaginable, who is now furiously changing the sleepy atoll to his peculiar aims, the only other introduced mammals are dogs and cats. The dogs are of many breeds, have many friends and many masters, and are treated far more humanely than in the Hawaiian Islands where neglected, starving and mangy curs abound. None of these dogs is thus forced to run wild to forage for itself, a habit that might be disastrous to the rookeries. Some, strangely enough, enter the shallow water of the lagoon for their peculiar form of sport fishing: pouncing upon an occasional unwary mullet that may swim by. Cats, escaped from domestication, have run wild and obviously take their toll of nesting sea birds.

All Canton crustaceans have aquatic larvae. But a few crustaceans have become adapted for life on land toward maturity. Such, for instance, are the fiddler crabs. I observed hundreds of these brilliantly colored, gregarious animals about their burrows in the pale mud along the lagoon's edge. But the crabs that are really best adapted to terrestrial life, arouse interest and cause worry are the countless small pale hermitcrabs Coenobita perlatus. Every small dead spiral mollusk shell - there must be hundreds of thousands available about Canton - houses one of these lopsided, soft abdomened animals. They are particularly numerous feeding on the jetsam along the beach facing the lagoon, and also penetrate inland. Here they may be found seeking protection from the heat of the day under branches, fallen leaves and coral slabs, and in shaded crevices. As these crabs increase in size their housing shortage, for lack of an abundant supply of large mollusk shells, must be so acute as to cause a catastrophe eventually among them. Only those that can find the comparatively rare, catseye shell (Turbo), measuring up to about three inches in diameter, survive. Even so, these mature hermitcrabs, now red like boiled lobsters, are numerous enough to over-run the island. To be sure, they are useful scavengers, cleaning the rookeries of dead fledglings, the shores of dead fish and lobsters and the land, in general, of all dead animal matter. But as this supply

is certainly insufficient to keep these creatures well fed, they obviously must feed also on plants, those living miles from the rookeries being per force mainly vegetarian. They seem to browse among the vegetation, and even climb kou trunks and branches as high as four and a half feet in search of food. They eat the bark along the upper side, most kou trees showing long scars, the result of past injury. A common habit, especially of the less heavy individuals is to cleverly tear off and eat only the ovary and stamens of the flowers of Portulaca lutea and of the local Sesuvium. In the latter, I also observed them boring out of the ovary the ripening seeds for food, These are certainly not isolated acts, but ones perfected by practice and perhaps instinct. They probably decimate the flora, feeding particularly on tender seedlings of certain species, which ones have not yet been determined. I believe these hermitcrabs are largely responsible for the paucity of different kinds of plants on Canton, any seeds of new kinds of plants washing to its shores being subject to their inspection on germination and, if palatable, sacrificed to their appetite. The foreign plants now being introduced as seeds and seedlings to Canton likewise must not only surmount the drastic conditions of drought and salinity, but must surmount the hurdle of voracious hermitcrabs.

Though a nuisance in many ways, these land hermitcrabs are used as bait and as chumming material. They are interesting and, to Canton, economically important creatures. We know far too little about them. A complete life history would be a fascinating problem for some resident of Canton to work out during his spare time. In the month of April, for example, the females carry their numerous maroon eggs attached to their abdomens. When do they return to the ocean to allow these eggs to hatch their free-swimming larvae, that resemble so closely the shrimp-like ancestor of all hermitcrabs? Where do the hermitcrabs molt their hard unexpanding shells as they grow in size? Do they do so in burrows on land or in the ocean? How, with gills adapted for respiration in water, have they perfected respiration on land? How long do they live? Must they leave their borrowed mollusk shell kilt to defecate, or can they remove their body wastes otherwise? I have observed a loving pair beside a bunch of grass not too tenderly clawing at one another with legs and chelipeds, at the same time uttering their subdued chick, chick, chick, chick - chick, chick, chick, chick love song. How do they emit this sound without a voice or hear it without ears? Scores of similar questions remain to be answered, not all academic ones.

Native spiders are rare in kinds. The wolf spider, which weaves no web, is everywhere, running about in the open on the ground in search of insects. It is very beneficial to the atoll, probably the most efficient insect killer, the second being the migratory plover. The female carries its flat egg case wherever it goes. This spider not only sucks the juices of its victim but comminutes, like its common relative the house spider of

Hawaii, their bodies to almost dust-like particles. A spider found more often in abandoned shacks and bushes is Latrodectus geometricus. It is mostly immobile in its sprawling web, and parks its spherical egg cases in a corner of it. Though related to the infamous black widow, no cases of bites from this arachnid are known from Canton.

The number of native species of insects are few, as expected considering the difficulty for these small terrestrial creatures crossing extensive wastes of ocean to Canton and, when once there, finding suitable fare with such a limited flora. There is some injury to native plants by native insects, but in the main this is not serious. They have always been exposed to such depredations, and survived. What is, however, very serious is the habit of amateur plant lovers introducing plants of their choice by boat and plane from Fiji, Hawaii and elsewhere without fumigation against insect pests. As a result Canton Island is a safe, enemy free Paradise for some foreign insects such as mealy bugs that harass native and introduced grasses, scale insects that weaken coconut palms about the hotel grounds, crater scale on the single remaining Plumeria, etc. This unnecessary introduction of insect pests not only adds one more hurdle for plants to surmount for survival, it likewise makes Canton a very dangerous stepping stone for the passage of injurious pests to and from all regions touched by planes using the atoll for refueling or otherwise. An up-to-date list of insects of Canton, collected by Van Zwaluwenburg, Degener and others, will be found in Atoll Research Bulletin 42, by R. H. Van Zwaluwenburg.

Amphibians are entirely wanting. Of reptiles a gecko with its glue-tipped toes may climb slowly about the island shrubbery, driftwood and rocks at night for insects; and a graceful skink, differing in color from those in the Hawaiian Islands, may rush over the level sand and smooth rocks during the day for his fare. This last, if careless, may be snapped up for food by the migratory plover. A turtle may occasionally climb out of the sea to lay her eggs in the warm sand of the beach. No other reptiles occur.

Of birds Bryan recorded the following from the Phoenix Islands: "the frigate or man-o'-war; three species of boobies or gannets; the red-tailed tropic bird or bos'n bird; several species of terns, including the sooty, gray-backed, noddy, small noddy, white, and gray; three or more species of petrels and shearwaters. Several kinds of migratory birds are to be found in the winter, during their migrations; a few may be found at other times. These include the curlew, Pacific golden plover, wandering tatler, turnstone, and a few others." The boobies and frigate birds take up a stretch of about eight miles of Canton for their rookeries. There are no native land birds on Canton, but about the British community the Gilbertese residents own interesting looking chickens, which never stray far.

A few red-tailed tropic birds (Phaeton rubricauda) nest under thick tangles of sida bushes or in cavernous retreats under coral rock ledges. They make a frightening, metallic, machine like noise when disturbed. These birds affect vegetation but little.

Black, vulture-like frigate birds (Fregata minor palmerstoni), known in Hawaiian as iwa or "thief," are extremely common, nesting by the thousands in the scaevola bushes and very rarely on bunchgrass. After driving through such a rookery, our windshield and car body were found to be finely bespattered with minute droplets of whitish excrement, that had rained down from the birds flying overhead. Occasionally a parasitic Hippoboscid louse fly, looking like a large flattened black housefly, is knocked off a frightened bird and flies to the car, mistaking its dark body for that of its host.

The nests are coarse, excrement soiled and cemented affairs constructed of twigs and driftwood. During rare downpours, this filthy binding material may dissolve away, allowing the eggs to fall to the ground. Nesting material is evidently rare and highly prized, giving rise to cases of theft, a bird in flight occasionally filching a loose piece from a carelessly guarded nest. The iwa will even stoop to murder and cannibalism, flying off with an egg or newly hatched young to eat on the wing. There is usually one egg to a nest, entirely white and a bit larger than that of a chicken. Both sexes take turns setting on the egg, and later sitting on or over the growing chick. This is not only necessary to incubate the egg and later keep the chick warm in cool weather, but also as protection from too intense sunshine. At that time the males are resplendent with blood red, semitransparent throat pouches blown to balloon size, extending forward to the beak and downward to hide the breast. This color is supplied by innumerable blood-filled capillaries in the tissue of the pouch.

Not far from the rookeries of the iwa or frigate birds, which act like the harpies of Greek mythology in stealing food from the more industrious, are the rookeries of the stupid red-footed boobies or gannets (Sula sula rubripes). The name booby is from the Spanish word bobo, meaning "dunce" or "idiot." At times the rookeries of the aggressive marauder and boob-victim overlap at the edges. The nests of the booby contain a single white egg or a fluffy fledgling apiece.

According to T. Truman Wright,* the frigate birds "escort the stupid, spoon billed Ganets out to feed on schools of squid and small fish. When the Ganets get craws full and set sail for home to feed their young, the cruel curve beaked Frigates dive screaming after them, seize them by the tails and sling the food out of the smaller birds' mouths, which the Frigates scoop up on the wing. This goes on from dawn to dusk. The war cries of the Frigates and the plaintive screams of fleeing Ganets

*Wright, T. T., Canton Coral Capers, Trade Winds, Mimeographed publication by C.A.A., July 1951.

quiver down the trade winds like the wailings of lost souls."

It is commonly reported that frigate birds, lacking webbed feet, never land on the surface of the water because they cannot take off again. This is not true. I have seen a small flock of them playfully land, float and rise again from the placid surface of the lagoon.

The birds nesting in the scaevola are tame or, depending upon one's point of view, too innocent and stupid to fly from their nests when approached. The explanation for this habit is their nesting from time immemorial in areas where no predatory animals, two- or four-legged, have ever existed. Tame birds were not killed off but survived to reproduce their kind. Now, unfortunately, Pacific islanders employed as laborers, occasionally club the nesting birds at night, preparatory to a feast. Such vandalism and resulting pandemonium in the rookeries should be stopped by legislation in a condominium involving two great humane nations.

The ancestors of these and other kinds of sea birds have inhabited Canton Island during the nesting seasons ever since its existence, catching fish, squid and other sea life for food for themselves and their fledglings. Their droppings have accumulated and, because of the climate, have only in part leached away - certain constituents disappearing faster than others. The remaining decomposed and more or less fossilized excrement is known as guano, rich in phosphates, ammonium oxalate and urate. Because of its commercial value as fertilizer, Canton, as we have learned before, first received attention from man.

Canton, a Beautiful Oasis in a Desert of Ocean

When the native flora, as in the case of Canton, is incapable of covering the land to protect it from blowing away and from making it decently habitable for man, proper exotics should be introduced to meet this lack. In 1950, as mentioned above, CAA therefore engaged the writer to begin to improve Canton floristically. Though a good beginning has been made, present residents should not remain satisfied. The seeds of so many more desirable and beautiful plants suitable for Canton are waiting for them in the arid, saline regions of the tropics. They can import these to make their atoll an ever more beautiful oasis in a desert of ocean. They can show how bare islands through the tropics can be made decently livable for the ever-increasing hordes of mankind seeking a place in the sun - a fascinating challenge!

Appendix A

Excerpt from a letter to the author from Mr. Myron H. Kerner, Meteorologist In Charge, U. S. Weather Bureau, Canton Island, dated Nov. 25, 1954..

The statements regarding the local heating effect are in serious variance with the accepted theories. If vertical currents are created by local heating of the atoll of Canton, the effect would increase the amount of cloudiness and resulting rainfall, not divert it. As air is lifted, it is cooled adiabatically and if lifted far enough, will condense. Lifting may be caused when air is heated locally or when it climbs up the slope of terrain or up the slope of a more dense air mass or by converging air masses. Once started and with the initial force removed, it may or may not continue to rise, depending upon the vertical temperature distribution of the air mass. If the atoll afforded any of the lifting forces there should be a marked increase in cloudiness as a result but there appears to be no difference in cloudiness between that over the atoll and that over the ocean. In my 16 months of continous duty here, I have never observed any deviation in a cloud's course due to the island and there appears to be no reason to believe that the island has any effect on the rain.

Our precipitation is caused in three different ways. There are always some cumulus present; these are probably a result of local heating due to distant variation in the sea surface and converging air. Precipitation from these clouds is infrequent, light and spotty. The greatest amount occurs when the inter-tropical convergence zone (the narrow band where the trade winds converge on the doldrum belt giving large scale up lift to the air resulting in thunderstorm activity and copious rain showers) lying to the south of us moves over us for a few hours to a few days. Then Canton may get several inches in a day. The third source of precipitation results from small scale equatorial low pressure systems that move slowly from the Gilberts. The occurrence of precipitation from either of these latter two reasons is very irregular, which accounts for Canton's being a place of great extremes in seasonal precipitation.

However, there does appear to be a diurnal variation in precipitation, based on 26 months of record available since the installation of our recording rain gage. This period is still too short to come to any quantitative conclusions, but during this time over one half of the precipitation fell between the hours of midnight and 8:00 a.m. Of course, the diurnal variation in ocean temperature results in a slightly greater instability at night and we should expect more cloudiness then.

ATOLL RESEARCH BULLETIN

No. 42

The insects and certain other arthropods of Canton Island

by

R. H. Van Zwaluwenburg

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences--National Research Council

Washington, D. C.

August 15, 1955

The Insects and Certain other Arthropods of Canton Island

R. H. Van Zwaluwenburg

The basis of the present list of arthropods known to occur on Canton Island, in the Phoenix group, is the writer's paper "The Insects of Canton Island", which appeared in 1943 in the "Proceedings" of the Hawaiian Entomological Society (vol.11: 300-312). Ninety-six species were listed in that paper. Since then, following increased air transportation to and from Canton during the recent war, several additions have been made to the fauna of the atoll. Besides including the new records, the present list corrects a few earlier errors of identification, omits some doubtful records, and supplies synonymous names whenever these have been discovered.

CRUSTACEA

Isopoda

Metaponorthrus pruinosus Brandt. Under heaps of old coconuts.

Undetermined sp. Found in similar locations with the preceding sowbug.

Amphipoda

Undetermined sp. Beneath stranded timbers on the lagoon beach.

ARACHNIDA

Scorpionoidea

Isometrus maculatus Degeer. Occasionally found in buildings.

Araneida

Lycosidae

Undetermined sp. In and about buildings.

Sicariidae

Scytodes sp.

Oonopidae

Gamasomorpha minima Berland. Described from Canton Island in Bishop Museum, Occ. Papers, 17 (1): 5, 1942.

Pholcidae

Undetermined sp. A single specimen in a building, September, 1941.

Theridiidae

Latrodectus mactans (Fabricius). The black widow spider was first found on Canton in July, 1949.

Argiopidae

Undetermined sp. The orb-webs of a spider are conspicuous about buildings.

Acarina

Gamasidae

Laelaps sp. On the ground-nesting Polynesian rat. Dr. C. E. Pemberton studied this material and reports that the Canton species more closely resembles Laelaps hawaiiensis Ewing, than L. echidninus (Berlese).

Listrophoridae

Listrophorides sp. A hair mite on the Polynesian rat.

Oribatidae

Undetermined sp. In vegetable mould under Sesuvium plants.

Ixoidea

Argasidae

Ornithodoros sp. The exuvium of an argasid tick was found on a shrub; no other material is available.

MYRIOPODA

Chilopoda

Mecistocephalus maxillaris (Gervais). In soil beneath old coconuts, and under sacking in outbuildings. The species is probably the same as that occurring in Hawaii.

INSECTA

Thysanura

Lepismidae

Undetermined sp. A single specimen among papers.

Collembola

Entomobryidae

Undetermined sp. One or more species in moist soil beneath old coconuts.

Orthoptera

Blattidae

Cutilia soror (Brunner). Under bags on the beach, and in soil beneath fallen coconuts.

Periplaneta americana (L.). Common both indoors and out.

Pycnoscelus surinamensis (L.). This cockroach was found under coconuts.

Supella supellectilium (Serville). A single specimen was found indoors, November, 1940.

Blatta sp. Collected in the housing area by Degner in April, 1951.

Gryllidae

Gryllodes sigillatus (Walker). Numerous in dwellings.

Tettigoniidae

Aiolopus tamulus (Fabricius). First noted on Canton by N.L.H. Krauss in September, 1950, and more recently reported to be numerous. One of the few grasshoppers which is attracted to lights.

Note- The record of Conocephalus saltator (Saussure) from Canton was based on a dead specimen taken to the island in glassware from Honolulu; it should be deleted from the list.

ISOPTERA

Kalotermitidae

Kalotermes immigrans Snyder. Dr. A. E. Emerson considers Calotermes curvithorax Kelsey to be a synonym; this latter name was proposed for termites first found on Canton in May, 1937.

EMBIOPTERA

Oligotomidae

Oligotoma saundersii (Westwood). Not uncommon under dead birds, in soil beneath old coconuts and in debris of rats' nests.

DERMAPTERA

Labiduridae

Anisolabis eteronoma Borelli. A single specimen was found among plants brought from Honolulu in June, 1941. The species probably is not established on Canton.

ODONATA

Libellulidae

Diplacodes bipunctata (Brauer). First noted in June, 1941.

Pantala flavescens (Fabricius). First noted on Canton in February, 1941. Dragon fly populations on Canton presumably die out during adverse periods, but are continually being recolonized by adults flying in from other Pacific islands.

CORRODENTIA

Liposcelidae

Undetermined sp. Taken in vegetable mould under Sesuvium bushes.

Peripsocidae

Ectopsocus perkinsi Banks. One specimen collected by N. L. H. Krauss in September, 1950, was identified as this species by Dr. D. E. Hardy.

HOMOPTERA

Cicadellidae

Orosius argentatus (Evans). The synonym, Nesaloha cantonis Oman, was described from material first collected on Canton in August, 1940. This leafhopper has a wide range in the Pacific. On Canton it was numerous on Boerhavia diffusa and is suspected of being a possible vector of a "yellows" disease of Boerhavia leaves.

Aphididae

Aphis gossypii Glover. Very common on Portulaca lutea and on the introduced Coccolobis uvifera; less common on Sida fallax and Scaevola.

Coccidae

Asterolecanium pustulans (Cockerell). On Sida and on the introduced Thespesia populnea. Probably an introduction from Hawaii.

Chrysomphalus aonidum (L.). On coconut foliage and on introduced Callophyllum.

Coccus hesperidum L. On introduced milo and oleander; an accidental immigrant, probably from Hawaii.

Pinnaspis strachani (Cooley). This is the species previously listed from Canton as Hemichionaspis minor (Maskell), a misidentification. On Canton it was found on Tournefortia argentea.

Pseudococcus palmarum (Ehrhorn). On coconut; this is the species listed as Ripersia palmarum in the 1943 list of Canton insects.

Pseudococcus adonidum (L). On Scaevola; this is the species which earlier was recorded as P. longispinus (Targioni-Tozzetti).

Saissetia hemisphaerica (Targioni-Tozzetti). A probable immigrant from Hawaii, on introduced plants such as Hibiscus tiliaceus and Calotropis gigantea ("crown flower").

Undetermined sp. A mealybug was common on Sida, on the stem at the base of the plant, and on the leaves, which were distorted as a result of the infestation.

HETEROPTERA

Cydnidae

Geotomus pygmaeus (Dallas). At light.

Pentatomidae

Oechalia, probably consocialis (Boisduval). Nymphs and adults of this bug were taken in the housing area on Canton by Otto Degener in April, 1951. It is probably consocialis which is a widespread species in the Pacific and occurs on Fanning and Christmas islands to the northeast of Canton.

Nabidae

Nabis capsiformis Germar. This predaceous bug is common on low herbage; it was recorded earlier under the generic name Reduviolus.

Miridae

Campylomma near hawaiiensis Usinger. Collected in the housing area in April, 1951 by Otto Degener.

Trigonotylus brevipes Jakowlef. A nearly cosmopolitan grass-inhabiting bug. Two specimens were collected by Van Zwaluwenburg in August, 1940.

Cyrtorhinus zwaluwenburgi Usinger. Described from material swept from Boerhavia in 1940 ("Proceedings", Hawaiian Entomological Society, 12 (1): 148, 1944). Dr. Usinger suggests that this species which preys on leafhopper eggs, may, in the absence of Delphacidae on Canton, be feeding on the eggs of the cicadellid, Orosius argentatus (Evans).

Note- The undetermined mirid listed in the 1943 paper was later identified by Dr. R. L. Usinger as Pycnoderes quadrimaculatus Guerin. The species has not been seen on Canton since 1940, and there is good reason to believe it was brought there from Honolulu in a collecting bottle.

Gerridae

Halobates micans Eschscholtz. This marine strider is often found stranded on the ocean beach at Canton.

COLEOPTERA

Carabidae

Tachys mucescens Blackburn. Two specimens at light in June, 1941. Identified by E. C. Zimmerman as this species, known previously only from Hawaii.

Tachys sp. A single specimen in the hotel kitchen, March, 1941.

Histeridae

Carcinops quatuordecimstriata (Stephens). In bird droppings under rookeries.

Corynetidae

Necrobia rufipes (Degeer). The "copra" or "ham" beetle.

Elateridae

Conoderus pallipes (Eschscholtz). First taken on Canton by Otto Degener, in May, 1951.

Dermestidae

Dermestes cadaverinus Fabricius. Adults in dead mollusk shells.

Nitidulidae

Carpophilus hemipterus (L.).

Coccinellidae

Harmonia arcuata (Fabricius). Often numerous on Sida, the adults clustering on the undersides of the leaves. Also associated with Aphis gossypii on Scaevola; on Boerhavia the larvae have been observed to feed on droplets excreted by Orosius.

Anthicidae

Anthicus oceanicus Laferte. Under dead seabirds.

Tenebrionidae

Gonocephalum adpressiforme Kaszab. First taken on Canton in January, 1951, by Dr. P. M. Corboy. Occurs also on Luzon in the Philippines, and on Oahu.

Scarabaeidae

Pleurophorus parvulus Chevrolat. A single specimen taken in July, 1941.

Sarrosites pygmaeus Harris. One specimen in soil under old coconuts, September, 1940.

Anthribidae

Araecerus vieillardi (Montrouzier). First taken on Canton by Otto Degener, April 28, 1951.

Curculionidae

Calandra oryzae (L.). In hotel kitchen.

Dryotribus rimeticus Horn. Two specimens taken by N.L.H. Krauss in September, 1950.

LEPIDOPTER A

Tineidae

Petrochroa dimorpha Busck. This tiny moth feeds in the dead trash about bunchgrass clumps, and is often exceedingly abundant. It occurs on Wake Island also.

Hyposmocomidae

Aphthonetus sp. Taken at light; first noted in October, 1940.

Pyralidae

Hymenia recurvalis (Fabricius). Adults come to lights; the larvae will probably be found to feed on Amaranthus on Canton.

Arctiidae

Utetheisa pulchelloides Hampson. Breeds on Tournefortia, on the leaves of which the early stages of the larvae produce a "window pane" effect.

Phalaenidae

Achaea janata (L.). The larvae feed on Cordia subcordata.

Amyna octo Guenee. The green caterpillars feed on Sida leaves.

Heliothis armigera (Hubner). The notorious "corn ear" worm, or "tomato worm".

Laphygma exempta (Walker). The larvae of this armyworm feed on bermuda grass, and on the bunch grasses, Digitaria pacifica and Lepturus repens. An egg-parasite, Telenomus nawai was introduced from Honolulu in 1941, and promptly began breeding in Laphygma eggs; it is not known if it still survives on Canton.

Prodenia litura (Fabricius). On Canton the larvae of this destructive species feed on Lepturus, Digitaria, Sida, tomato and sweet-potato.

Undetermined sp. Irregular feeding holes are common on Scaevola leaves, made by a bright-green caterpillar probably belonging to this family of moths. The damage is conspicuous, but during my stay on the island caterpillars were rare. Apparently they feed by night and hide in the sand during the day. Attempts to rear caterpillars to the adult stage were unsuccessful.

Danaidae

Danaida plexippus (L.). Occasional tattered specimens of the monarch butterfly were seen on Canton during 1940 and 1941, but the species was not breeding there at that time. Since then occasional fresh specimens have been taken which suggest that they are breeding locally, perhaps on the introduced crown-flower.

Nymphalidae

Hypolimnas bolina (L.). Well established in 1941 and breeding on Sida.

DIPTERA

Mycetophilidae

Undetermined sp. On soil under old coconuts.

Tendipedidae

Undetermined sp. On native vegetation.

Sciaridae

Undetermined sp. On vegetation.

Dolichopodidae

Chrysosoma sp.

Hydrophorus sp. Abundant on brackish pools.

Syrphidae

Ischiodon penicillatus (Hull). This fly was misidentified as Ischiodon scutellaris (Fabricius) in the 1943 list.

Lonchaeidae

Lamprolonchaea aurea (Macquart). First taken on Canton by Krauss in September, 1950; identified by D. E. Hardy.

Otitidae

Pseudeuxesta prima Osten Sacken. Determined by D. E. Hardy. A synonym is Euxesta semifasciata Malloch. This is probably the Euxesta sp. of the 1943 list, on bits of organic matter along the beach.

Scholastes bimaculatus Hendel. Breeds in rotten meat of green coconuts.

Tethinidae

Tethina insularis Aldrich.

Ephydridae

Hecamede persimilis Hendel.

Paralimna lineata de Meijere. Collected in November, 1940 by R. R. Danner; identified by Dr. W. W. Wirth.

Scatella sp. On brackish ponds.

Agromyzidae

Ophiomyia scaevolae Frick. A leafminer in Scaevola frutescens; it is parasitized by a eulophid, Pnigalio sp. The description of O. scaevolae appeared in the "Proceedings" of the Hawaiian Entomological Society, 15:209, 1953.

Milichiidae

Desmometopa m-nigrum Zettersted. Breeds in dead mollusks.

Milichiella lacteipennis (Loew). Common, hovering over foliage.

Chloropidae

Cadrema pallida (Loew). In the 1943 list as Prohippelates.

Siphunculina signata Wollaston. Not common.

Muscidae

Atherigona excisa trilineata Stein.

Musca domestica L.

Calliphoridae

Phaenicia sericata (Meigen). Bred from dead rat; very common.

Sarcophagidae

Sarcophaga dux Thomson. Very common.

HYMENOPTERA

Evaniidae

Evania appendigaster (L.). This species was introduced to Canton from Honolulu in August, 1940, and soon became well established in the egg-cases of Periplaneta americana. It apparently continues to be present, for Otto Degner collected a specimen in May, 1951.

Eulophidae

Pnigalio sp., probably external (Timberlake). This insect was bred from mines of the agromyzid leafminer in Scaevola, Ophiomyia scaevolae (called Notonisomorphomyia in the 1943 list).

Note - In September, 1941, adults of Euplectrus plathpenae Ashmead, were brought to Canton from Honolulu to parasitize the larvae of Laphygma. There appears to be no evidence that this wasp became established.

Scelionidae

Telenomus nawai Ashmead. This egg parasite of Laphygma exempta was introduced from Honolulu in August, 1941, and one month later was reared from eggs of the army worm moth. It is not known if it still survives on Canton.

Formicidae

Tetramorium Guineense (Fabricius).

Tetramorium simillimum (F. Smith). In soil beneath piles of coconuts, etc.

Tapinoma melanocephalum (Fabricius). On Sida plants.

Camponotus variegatus hawaiiensis Forel. The first specimens of the carpenter ant to be known from Canton, were collected there in the housing area by Otto Degener in April, 1950.

Paratrechina longicornis (Latreille). The "crazy ant" was the dominant species on Canton in 1940-41.

Paratrechina bourbonica hawaiiensis Forel..

Sphecidae

Sceliphron caementarium Drury. This mud-dauber wasp was first collected on Canton by N. L. H. Krauss in October, 1950. It was collected subsequently by Degener also.

Vespidae

Pachodynerus nasidens (Letreille). First collected on Canton by J. P. Martin on December 30, 1946. It appears to be abundant there now.

Megachilidae

Undetermined sp. Found as early as November, 1941. A series was collected later by Degener.

- - - - - - - - - - - - -

Numerical summary of Canton Island arthropods

Isopods	2	Insects	
Amphipods	1	Dermaptera	1
Scorpions	1	Embioptera	1
Spiders	6	Dragon flies	2
Mites	3	Corrodentia	2
Ticks	1	Homoptera	10
Myriopods	1	Heteroptera	7
Insects		Coleoptera	15
Thysanura	1	Lepidoptera	12
Collembola	1	Diptera	22
Orthoptera	7	Hymenoptera	12

The above list gives a total of 108 arthropods, 93 of them insects, and 15 belonging to related orders.

6-3-54

ATOLL RESEARCH BULLETIN

No. 43

The natural vegetation of Canton Island, an equatorial Pacific atoll

by

William H. Hatheway

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences--National Research Council

Washington, D. C.

August 15, 1955

The natural vegetation of Canton Island, an equatorial Pacific atoll.

by
William H. Hatheway 1/

INTRODUCTION

Canton Island (Lat. 2° 50'S., Long. 171° 38'W), a British-American condominium situated in the Phoenix Group, has gained in political and economic importance since 1939, largely because Pan-American Airways in that year established a permanent refueling station there, building a hotel on the south side of the island. In 1946 the United States Civil Aeronautics Administration set up a base on Canton. The island was occupied by United States military forces during the war years 1942-1945, when extensive construction and grading work was done. Before 1939 the island was uninhabited, being visited only infrequently by occasional guano diggers (Bryan 1942).

At the request of Mr. Garrison Costar, of the Civil Aeronautics Administration, a floristic and vegetational survey of Canton Island was conducted by Dr. Otto Degener and the author from July 11 to July 19, 1950. The island was revisited by the author in February 1951 and by Dr. Degener in April and May 1951. As a result of these surveys, recommendations were made leading to the introduction of many species of ornamental and otherwise useful plants. This paper is a report on the structure, distribution and ecology of the natural vegetation of Canton Island.

PHYSICAL ENVIRONMENT

Canton Island is a coral atoll approximately 21 miles in circumference (Fig. 1). The land surface is at no place wider than 3200 feet, and maximum elevation is about 20 feet above mean sea level. Local relief is slight, but a considerable proportion of the land surface is of sufficiently low elevation to be subject at high tide to the influence of a brackish water table. Such swales are occupied by a characteristic vegetation, as is discussed below, Along the ocean side of the northern portion of the island high dunes have formed, and the scanty vegetation of Triumfetta procumbens which occurs there has a distinctly xeric aspect.

The soil of Canton Island is derived from fragments of coral rock and calcareous sand deposited by waves and wind on a reef flat. Its texture is mostly rather coarse. In all places investigated a dark brown layer, from 7 to 15 inches thick, underlies the upper inch of sand or coral rock, or occurs at the surface of the ground. This dark layer, which contains a large proportion of guano, is believed to be of considerable significance in the development of the present vegetation of Canton Island.

During most of the year Canton Island is hot and humid, although actual precipitation is scanty. Mean annual rainfall is about 19 inches,

---

1/ The Rockefeller Foundation, Medellin, Colombia.

only the months March through August receiving over one inch of precipitation, on the average. Indeed, the months September through February constitute a well defined dry season, which attains its greatest intensity, on the average, in November. Extremely heavy precipitation has been reported in two years. In 1940, 70.60 inches of rainfall were recorded, while in the first eight months of 1941, 90.80 inches were reported. The records are to be interpreted with some caution, for there are indications that in at least one case data was incorrectly reported. It is undoubtedly true, however, that exceptionally heavy precipitation was received in those years, since Van Zwaluwenburg (1943) has shown by photographs the unusually luxuriant vegetation that developed in 1941, and stated that pools of standing water were of sufficient duration to allow insects with aquatic larvae to complete their life-cycles. Additional evidence for the great variability in annual rainfall on Canton can be derived from reliable records of only 8.46 inches total precipitation in 1947 and as much as 33.17 inches in 1948. It should also be emphasized that exceedingly heavy downpours often are followed by weeks of drought: thus the total precipitation of even a wet month may be received in two or three storms.

Very little variation in temperature occurs throughout the year. Mean annual temperature is about 84°F. The maximum recorded temperature for the three year period 1947-1949 was 98°F., the minimum 71°F. Relative humidity is constantly rather high, varying from a recorded minimum of 57 per cent to a maximum of 85 per cent. Average relative humidity at 1 p.m. is about 62 per cent. A very constant strong easterly wind is an outstanding feature of the Canton climate, and may affect the development of the natural vegetation. Planted ornamental trees and shrubs are commonly severely wind-clipped. Salt spray is undoubtedly a factor contributing to the stunting of the vegetation in some locations on Canton.

FLORA

The native flora of Canton Island is not rich, consisting of 14 species of vascular plants in as many genera. In addition, approximately 150 species have been introduced as ornamentals or adventive weeds. With only a few exceptions, the native flora is composed of wide-ranging Indo-Pacific strand plants, of which Scaevola frutescens may be cited as a typical example. The fruits or seeds of most of these species exhibit striking adaptations for floating.

The native vascular flora is largely confined to those parts of Canton Island which have not been subject to grading or other cultural operations. A weedy flora best characterized by the troublesome but short-lived sandbur, Cenchrus echinatus, dominates the semi-natural vegetation in the vicinity of the Pan-American Hotel, the Airlines Terminal, and the CAA Housing Areas during the wetter months of the year. It is a striking fact that this introduced flora has had very little tendency to invade the vegetation of those parts of the island which have not been subject to much human disturbance. Since this paper is concerned only with this "natural" vegetation, no further reference to the weed flora will be made.

NATURAL VEGETATION

The natural vegetation of Canton Island can be conveniently separated into three major types: communities dominated by trees, shrubs or herbs. All are relatively simple in composition and can easily be delineated on a map (Fig. 1). The results of planimeter measurements of the areas dominated by the plant communities recognized on Canton Island are presented in Table I.

TABLE I

Approximate areas included in the plant communities of Canton Island

Vegetation Type	Per cent of total land area	Per cent of land area covered by native vegetation	Approximate area in acres
Cordia forest	0.29	0.81	8.3
Messerschmidia forest	1.05	2.92	30.0
Scaevola scrub	6.17	17.11	176.0
Suriana-Sesuvium flats	88.58	23.80	244.9
Portulaca herbaceous community	19.96	55.37	569.6
Areas naturally bare	23.37	---	667.0
Disturbed areas	40.60	---	1,158.7
Total	100.02	100.01	2,854.5

The Cordia Forest--Well developed stands of Cordia subcordata exist today only on the south side of the island, less than one mile from Musick Light (Fig. 1). There two groves of trees flourish, covering about 3500 and 2700 square feet respectively. Other small groves of Cordia occur scattered around the island, but in those the trees are mostly leafless and in some cases actually dead.

The two groves of vigorous trees consist of pure stands of Cordia averaging about 19 feet in height; the tallest tree observed was 24 feet tall. Both forests are in reality nearly impenetrable thickets. Since Cordia on Canton Island reproduces chiefly by ground layering, the numerous shoots arising from decumbent branches make walking through the grove in a straight line virtually impossible. On the basis of a sample plot of approximately 400 square feet, in which 23 upright stems between 2 and 9 inches in diameter were counted, basal area was approximately 272 square feet and density about 2450 stems per acre. Average height to the first branch was only 29 inches, greatest length of clear bole being 75 inches. Light reaching the ground level in Cordia forest is rather diffuse; intensities as measured with a Weston photographic light meter inside the grove were only 5 to 10 per cent of those obtained outside. The ground is littered with dead branches, fruits, and a few leaves. Reproduction from seed within the grove is practically non-existent, but many Cordia seedlings which had recently germinated were observed near the periphery of the groves, most of them severely wilted. A small pit dug in the soil

inside the larger grove revealed a very dark sandy loam extending from the ground surface to a depth of about seven inches. Underlying the dark horizon was a layer of coarse sand which graded into fragments of coral rock and sand at a depth of 10 to 21 inches. The dark surface layer is interpreted as being composed chiefly of a mixture of guano and sand with addition of humus derived from rotting leaves and wood.

The Cordia groves are during the heat of the day a shelter for land hermit crabs (Coenobita perlatus). Large numbers of crabs may be found under fallen logs and branches and even climbing in the trees; two hermit crabs were discovered perched in a tree 69 inches above the ground. The crabs seem to do little damage to the trees. In some cases, however, young shoots have been stripped of bark and this mischief possibly may be attributed to the crabs.

A much more serious enemy of Cordia is the moth Achaea janata (L.) Caterpillars were abundant in both groves in July 1950, and it was observed that many shoots had been completely defoliated by these insects; nearly every leaf showed some damage. About 8 months later the author observed that the smaller of the two groves had been completely defoliated. Because of the depredations of this insect, it appears unlikely that Cordia subcordata will extend its range on Canton Island in the absence of control measures. This is unfortunate, since this tree is perhaps the most desirable species now known for purposes of afforestation. It is relatively large, has attractive flowers and foliage, and appears to be well adapted to the physical environment of Canton Island.

The Messerschmidia Forest--Only one healthy, well developed stand of Messerschmidia argentea exists on Canton Island. This grove is situated a few hundred yards west of the principal airstrip, on the north side of the island. Another grove consisting of dead or dying trees was found southeast of the "fighter airstrip," and many isolated trees grow scattered about the island.

The healthy grove was studied in some detail. It was 158 feet long and from 35 to 51 feet wide; total area was about 7000 square feet, or 0.6 acre. The average height of the trees was about 15 feet, the largest tree in the grove being 19 feet tall. Like the Cordia forest, the Messerschmidia grove was in most places a tangle through which one proceeded only with difficulty. The trees branched at an average of 18 inches above the ground, and reproduction within the grove was apparently entirely by root suckers. A sample plot of 675 square feet was set out inside the grove, within which 18 living upright stems between two and eight inches in diameter were counted. The calculated density was therefore about 1160 stems and the basal area approximately 132 square feet per acre. Thus both in density of stems and basal area the figures for Messerschmidia forest were about one half those obtained in Cordia forest. The light intensity at ground level was correspondingly greater than in Cordia forest, being about 25 per cent of that outside the grove. Possibly because of the relatively high light intensity, a scattering of plants of Portulaca lutea, Boerhavia tetrandra, Setaria verticillata and Lepturus repens, all shade-intolerant plants, were established in the understory of the Messerschmidia grove. Soil profile studies revealed a

pattern similar to that in the Cordia grove. A dark sandy loam, presumably derived chiefly from coral sand, guano and leaf and branch litter overlay a light-colored sand, which contained fragments of coral rock.

Like the Cordia grove, the Messerschmidia forest is a favorite shelter during the warm daylight hours for large numbers of hermit crabs. No damage attributable to the crabs or to insects may be observed in the grove. It is believed that the crabs forage chiefly by night, but feeding habits are imperfectly known. One crab was observed to devour a flower of Portulaca lutea, however, and it is suspected that damage done to planted New Zealand spinach (Tetragonia tetragonioides) may be attributed to the crabs.

The Scaevola Scrub--On Canton Island Scaevola frutescens becomes a shrub ten feet tall and in some places nearly 50 feet in diameter. Reproduction proceeds radially from the oldest and tallest plant in the center of a clump, so that what may appear to be a single enormous bush may actually consist of many individuals belonging to several generations. Scaevola occurred in extensive, nearly pure stands at the southeast corner of Canton Island; other species occurring occasionally in the Scaevola scrub are Messerschmidia argentea, Sida fallax, Boerhavia tetrandra and Portulaca lutea.

In order to determine the approximate density of the Scaevola scrub, a sample plot of 625 square feet was laid out in a randomly selected area within the vegetation type. 12 Scaevola bushes were counted, the tallest eight feet high. This is a density of one bush per 52 square feet. Along a 1000-foot line transect, 115 bushes were counted, or one bush per 8.7 feet. The surface horizon of the soil is a stony sandy loam, containing considerable amounts of guano.

An interesting feature of this tract of Scaevola scrub is the enormous number of seabirds roosting and nesting in the shrubs. Frigate birds (Fregata minor palmerstoni) and red-footed boobies (Sula sula rubripes) predominate. In July many adults, young and eggs of both species were observed, but by February the boobies had largely disappeared. To estimate the number of birds roosting in a single bush, counts were made on the night of July 16 in the Scaevola scrub in the southeast corner of the island. Five bushes, each about 10 feet tall and ranging in area from 300 to 2000 square feet each were studied. As many as 45 birds were counted in a single bush; the average population for the five bushes studied was 34 birds per bush, that is roughly one bird per 30 square feet of bush. It appears not unlikely that the principal factor limiting the size of the Canton Island bird population is the absence of more such roosting and nesting sites. Indeed, at times the bushes are so crowded that frigate birds are forced to roost on the Sida fallax plants: these are spindly dwarf shrubs only about 10 to 12 inches high, and form a very insecure perch for a large bird. It is the opinion of the author that the large populations of roosting sea birds, which tend to congregate in relatively small areas, are of great significance in the development of the present natural vegetation of Canton Island.

The Suriana-Sesuvium Flats--Bordering extensive areas of tidal mudflats or covering small pockets of land influenced by the diurnal variation in the depth of the ground-water table is a plant community dominated by Sesuvium portulacastrum and Suriana maritima. The former is a fleshy decumbent herb, which occurs in striking bright green mats about 20 to 50 square feet in size. It usually occupies the centers of swales, or occurs near the high-tide level of mudflats of the sheltered lagoon side of the island. Suriana is a woody shrub, commonly about four feet tall, with fleshy yellow-green leaves. It characteristically borders the Sesuvium mats on the gently sloping edges of mudflats and swales. Large numbers of frigate birds are commonly observed in bushes of Suriana maritima.

The Portulaca Herbaceous Community--Portulaca lutea, together with Lepturus repens, Boerhavia tetrandra and Sida fallax dominates by far the largest area of natural vegetation on Canton Island. Portulaca lutea on Canton averages 6.5 inches in height and about 12 inches in lateral spread. It has a very fleshy taproot and main stem, up to one inch in diameter, and many branches radiating from the stem, each about 0.3 inches in diameter. Lepturus repens is a caespitose grass up to 19 inches in height (but averaging about 11.5 inches). It propagates itself at the periphery of clumps by ground-layering. The mats thus formed are occasionally quite extensive, the largest measured being 17.6 feet long and 9.3 feet wide, but covering only about 100 square feet. Generally, however, the clumps cover only about 1.25 square feet, the average diameter of the clumps being about 15 inches. Boerhavia tetrandra is a trailing vine with a large fleshy taproot up to 1.5 inches in diameter. Sida fallax, a dwarf shrub seldom over 12 inches tall on Canton Island, is a very common member of the community.

The Portulaca herbaceous community was studiede quantitatively at two stations about nine miles apart. As is suggested by the data in Tables II and III, Portulaca is a consistent dominant in the community, while the frequency and cover degree of its associates are somewhat variable. In general it appears that the abundance of Sida and Boerhavia is correlated with a somewhat stony soil phase, while Lepturus is more prominent in areas of even-textured sand.

TABLE II

Frequency and Foliage Cover in the Portulaca Herbaceous Community. Data from five meter-square plots. Station I, about 10 miles by road from "Turning Basin."

Species	Frequency	Foliage Cover (Per cent)
Portulaca lutea	100	42
Lepturus repens	60	3
Sida fallax	40	2
Boerhavia tetrandra	20	5
Total		52

TABLE III

Frequency and Foliage Cover in the Portulaca Herbaceous Community. Data from 10 square-meter plots. Station II, about 19.5 miles by road from "Turning Basin."

Species	Frequency	Foliage Cover (Per cent)
Portulaca lutea	100	22
Sida fallax	100	18
Boerhavia tetrandra	100	15
Total		55

Beaches, Dunes and other naturally Bare Areas--About 23 per cent of the land surface of Canton Island has little or no natural vegetation cover. Such areas include beaches and other places subject to ocean wave action, and high dune. Triumfetta procumbens, a creeping perennial vine occurs occasionally on dunes on the north side of the island but its cover degree is very low. Ipomoea pes-caprae, which often is predominant in such situations in the Pacific is very rare on Canton Island. Only a single plant of this species was found in 1951, growing among rocks near fortifications erected in the war. It may have been planted by a soldier. Lepturus repens, reported by Christophersen (1937) to be characteristic of beach crests and shifting dunes on other Pacific equatorial islands, was not found in these sites on Canton.

DISCUSSION

The most striking features of the natural vegetation of Canton Island are the areal predominance of the Portulaca herbaceous community and the paucity of forest. This is perplexing in view of the fact that two native trees, Cordia subcordata and Messerschmidia argentea, are known in certain instances at least, to grow vigorously and to reproduce from seed. The forest communities thus formed tend to exclude the shade-intolerant herbaceous species of the Portulaca community. Moreover, the large shrub, Scaevola frutescens, is apparently invading the Portulaca herbaceous community about 9.5 miles by road from the "Turning Basin," on the north side of the island and possibly in other places. A relatively open stand of Scaevola might form a nurse crop favorable for the establishment of occasional seedlings of Cordia and Messerschmidia. Seedlings of Cordia soon wilt after ferminating in the open herbaceous communities. It is quite possible that existing groves of Cordia and Messerschmidia may be traced to the successful establishment of single seedlings which by vegetative propagation have come to occupy their present areas. Thus it would appear that in the absence of disturbing factors the development of the natural vegetation of Canton Island might trend toward greater areal extent of forest and scrub, at the expense of the hearbaceous communities.

It is evident, however, that such development is in process in only a few localities. Indeed, in most places the trend appears to be taking a different direction. Patches of native forest and scrub which are

situated more than one mile from human habitation are generally dead or dying. Extensive areas of Messerschmidia and Cordia forest about 10 miles by road from the "Turning Basin" are leafless and apparently dead. Counts of Scaevola bushes 16.5 miles from the "Turning Basin" revealed in a 1000-foot strip 35 vigorous plants, 40 dying plants and 40 dead ones. In a 625 square-foot plot, seven dead and five living bushes were counted.

Since healthy groves of Cordia and Messerschmidia exist on Canton Island possible climatic deterioration is not sufficient to explain the dying condition of most stands. No evidence has been found that the healthy stands owe their vigor to any possible cultural operations carried on within them. Instead, there is much evidence that a causal connection exists between the dead or dying condition of native forest and scrub in areas not affected by human activity and the enormous populations of fish-eating seabirds which roost and nest in the trees and shrubs. The arguments favoring such an hypothesis are listed briefly below:

1. Patches of native forest and scrub heavily populated with frigate birds and boobies invariably show high proportions of dying or dead trees and shrubs.

2. Patches of native forest and individual volunteer shrubs of Scaevola near human habitation and not visited by frigate birds and boobies are vigorous except when damaged by insects. Only Cordia exhibited noteworthy insect injury.

3. Soil profile studies in the Portulaca herbaceous community show beneath the surface inch of bleach sand a dark brown sandy loam to a depth of 15 inches. This dark layer is indistinguishable in the field from the guano soil at present developing under dying Messerschmidia, Cordia and Scaevola. The frigate birds and red-footed boobies at present visit only the forest and scrub, and other, smaller birds were observed only occasionally in the Portulaca community. It is suggested, therefore, that those areas in the Portulaca community exhibiting guano soil profiles were once covered with forest or scrub supporting large populations of roosting and nesting seabirds, at which time the guano was formed.

The mechanism by which birds might damage or destroy the native forest and scrub is not clear, although it appears likely that highly concentrated bird droppings might be as damaging to the trees and shrubs as would be excessive doses of nitrate and phosphate fertilizer. Stewart (1933) reported that roosting blackbirds severely injured a plantation of White Pine (Pinus strobus L.), and demonstrated that the concentration of soluble nitrates in the area of dying trees was enormously greater than in the unaffected area. The present author has conducted no experiments on the nature and properties of Canton Island guano soils. It is the experience of CAA personnel stationed on Canton, however, that ornamental plants potted in guano soil obtained from Canton Island forests grow much less vigorously than those potted in coral sand from the beach; these observations have been confirmed by the writer.

SUMMARY

1. Canton Island is a coral atoll situated at Lat. 2° S, Long. 171° W, in the Phoenix Group, Pacific Ocean. The total land area of the island is about 2,850 acres.

2. The climate is warm and humid, but rainfall is scanty and seasonal.

3. The native flora is scanty consisting chiefly of a few wide-ranging Indo-Pacific strand plants.

4. Natural vegetation consists of forests of Cordia subcordata and Messerschmidia argentea, scrub of Scaevola frutescens and Suriana maritima, and herbaceous communities dominated by Portulaca lutea. The last is much the most extensive type of natural vegetation on Canton Island.

5. Most native forest and scrub is in a dead or dying condition. It is suggested that the agents chiefly responsible for the death of native woody species are frigate birds, red-footed boobies and other fish-eating seabirds, which roost in enormous numbers in the forest and scrub. Observations are presented suggesting that certain areas presently covered by Portulaca and its associates formerly may have been dominated by forest or scrub. It is believed that in the absence of large populations of birds, native forest and scrub would tend to extend their present areas at the expense of herbaceous communities.

LITERATURE CITED

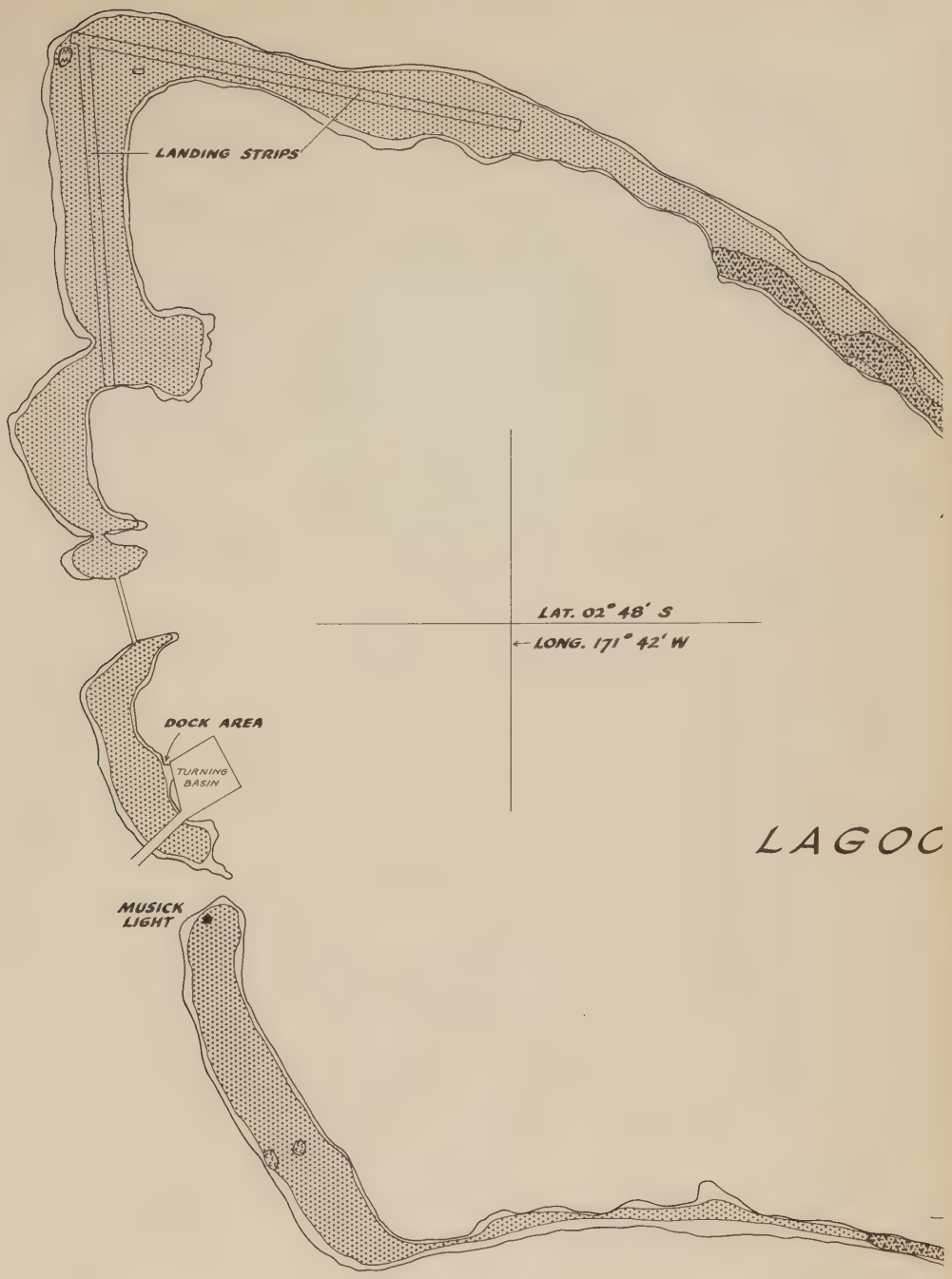
Bryan, E. H., Jr.
American Polynesia and the Hawaiian Chain.
1-253, Honolulu, 1942.

Christophersen, E.
Vegetation of Pacific Equatorial Islands.
Bishop Musem Bulletin 44: 1-79, pl. I-VII, 1927.

Stewart, G. R.
Forest plantations injured by roosting birds.
Jour. Forestry 31: 421-423, 1933.

Van Zwaluwenburg, R. H.
The insects of Canton Island.
Proc. Hawaiian Ent. Soc. 11(3): 300-312, 1943.

Valuable manuscript criticisms have been received from O. Degener, F. E. Egler, and F. R. Fosberg. The author is indebted to Mr. Edwin Gillaspy, Station Manager, Civil Aeronautics Administration, Canton Island, and Mr. William Cowdon, Pan-American Airways, Canton Island, for many courtesies extended during his visits to Canton Island.



CANTON ISLA
PLANT HABITA

DISTURBED BY BULL-DOZI
PORTULACA - LEPTURUS - BO
MESSERSCHMIDIA WOODL
SCAEVOLA SCRUB
SURIANA - SESUVIUM FLA
CORDIA GROVE

N
MAGNETIC 1948
TRUE
2000' 1000' 0' 2000' 4000'
SCALE: 1" = 1667'
GHTER
TRIP
N
LAT. 02° 50' S
← LONG. 171° 40' W
VD
OPERATIONS
AVIA

ATOLL RESEARCH BULLETIN

No. 44

The hydrology of Ifalik Atoll, Western Caroline Islands

by

Ted Arnow

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences--National Research Council

Washington, D. C.

August 15, 1955

CONTENTS

	Page
Introduction	1
Geographic setting	1
Climate	2
Tides	2
Water supply	7
Rainwater	7
Ground water	7
Occurrence	7
Quality	9
Use of water	14
Selected references	15

ILLUSTRATIONS

Figure 1.	Outline map of the Western Caroline Islands	2a
2.	Outline map of Ifalik Atoll, Western Caroline Islands, showing well locations	2b
3.	Tide graph in lagoon at Ifalik Atoll, September 14-25, 1953	2c
4.	Hydrograph for well 6, Ifalik Atoll	8a
5.	Mean water levels in wells, Falarik Island, Ifalik Atoll	8b
6.	Relation of damping of tidal fluctuations to distance of wells from shoreline, Falarik Island	12a
7.	Relation of lag of tidal fluctuations in wells to distance of wells from shoreline, Falarik Island	12b
8.	Relation of chloride content of ground water to distance from shoreline, Falarik Island, September 21, 1953	12c
9.	Relation of chloride content of ground water to distance from shoreline, Falarik Island, November 1 - 3, 1953	12d
10.	Relation of total hardness of ground water to distance from shoreline, Falarik Island, September 21, 1953	12e

TABLES

Table 1.	Rainfall at Ifalik Atoll, 1953	3
2.	Atmospheric pressure at Ifalik Atoll, 1953	4
3.	Relative humidity at Ifalik Atoll, 1953	5
4.	Air temperature at Ifalik Atoll, 1953	6
5.	Partial chemical analyses, in parts per million, of water from various sources in Ifalik Atoll	10, 11
6.	Chemical analyses of water samples, in parts per million, from Fan Ni Wa well line, Ifalik Atoll	13

THE HYDROLOGY OF IFALIK ATOLL, WESTERN CAROLINE ISLANDS[1/]

By

Ted Arnow [2/]

INTRODUCTION

The fieldwork for this report was done as a part of more extensive hydrologic investigations carried on by the U. S. Geological Survey in the Trust Territory of the Pacific Islands and was coordinated with the 1953 Scientific Investigation of Micronesia of the Pacific Science Board of the National Research Council, which was supported by funds granted by the Office of Naval Research by Contract N7onr-29104 (NR 388 001). Logistic support for the work was provided by the U. S. Navy, the U. S. Coast Guard, and the Trust Territory administration. Tide data were analyzed by the U. S. Coast and Geodetic Survey. The writer was on Ifalik from June 22 to 24, and September 12 to 26, 1953.

The Ifalik project was essentially a group undertaking of several specialists, each working in his own field but coordinating his activities with those of the others. The writer would like to express his gratitude to "Tom" Totogoeiti who supervised the digging of the observation wells, to Marston Bates who collected the bulk of the climatic data, and to D. P. Abbott who collected additional climatic and ground-water data after the writer left Ifalik. Geological studies and water-level determinations were made together with J. I. Tracey, Jr. Finally, appreciation is expressed to the people of Ifalik for their hospitality and assistance, without which completion of the project would not have been possible.

The primary purpose of this report is to present the data observed at Ifalik so that they may be available to other workers in the Pacific at an early date. A more comprehensive report of hydrologic conditions on Ifalik will be included in a later report which will cover all phases of the investigations on Ifalik.

GEOGRAPHIC SETTING

Ifalik Atoll is in the Western Caroline Islands, which are part of the Trust Territory of the Pacific Islands (fig. 1). Ifalik lies 360 nautical miles due south of Guam, 440 miles due west of Truk, and 400 miles southeast of Yap.

Ifalik is a small circular atoll having a total land area of 0.569 square statute mile and a lagoon area of 0.939 square mile (Bryan, 1946). The lagoon has one deep-water entrance. There are four islands - Falarik, Falalap, Ella, and Elangalap. (See fig. 2). Approximately 260 people live on Falarik and Falalap, but neither Ella nor Elangalap is regularly inhabited.

1/ Publication authorized by the Director, U. S. Geological Survey.
2/ Geologist, U. S. Geological Survey, Austin, Texas.

CLIMATE

The 1953 expedition to Ifalik obtained measurements of rainfall, atmospheric pressure, temperature, and relative humidity for a period of approximately 4 months. These data are shown in tables 1 to 4. The atmospheric pressure as measured daily between 0800 and 0900 hours ranged from 1004 to 1011 millibars (29.65 to 29.86 inches), 85 percent of the readings falling between 1007 and 1010 millibars. Relative humidity as measured between 0800 and 0900 hours ranged from 77 to 100 percent and averaged 86 percent.

Daily maximum and minimum temperatures were measured in the school building (see table 4) which is a thatched structure open on two sides. The extremes observed were 91 and 73 degrees Fahrenheit. The maximum daily range was 15 degrees, the minimum daily range was 5 degrees, and the average daily range during the 4-month period of observation was 11 degrees.

The rainfall measurements at Ifalik were made during the rainy season (see table 1). At least a trace was recorded on 83 percent of the days of observation, and the rainfall exceeded 1 inch on 11 percent of the days of observation. Although a total of 54.25 inches of rainfall was measured in only 131 days, it is probable that the average annual rainfall at Ifalik is between 100 and 120 inches. This estimate is based on a consideration of annual-precipitation data for Guam (91 inches, length of record, 41 years, Yap (119 inches, length of record, 27 years), Truk (127 inches, length of record, 7 years), and Lamotrek (104 inches, but only a 4-year record).

In general it can be stated that Ifalik has a tropical rainy climate with relatively small seasonal changes of the various climatic factors. The temperature and barometric pressure are monotonously uniform throughout the year and the most variable factors are wind and rainfall.

TIDES

Tide data were obtained for the period September 13 to 25, 1953, by means of a Stevens type-F water-level recorder which was placed in the lagoon near Falarik Island (see fig. 2). Part of the actual tide record is shown in figure 3. The tide data were analyzed by the U. S. Coast and Geodetic Survey, which computed the following elevations shown in feet:

Mean higher high water	0.95
Mean high water	0.75
Mean sea level	0.00
Mean low water	-0.75
Mean lower low water	-1.55

The primary benchmark established in Ifalik is an "X" chiseled in a limestone slab on Falarik Island. The slab is embedded in the ground 20

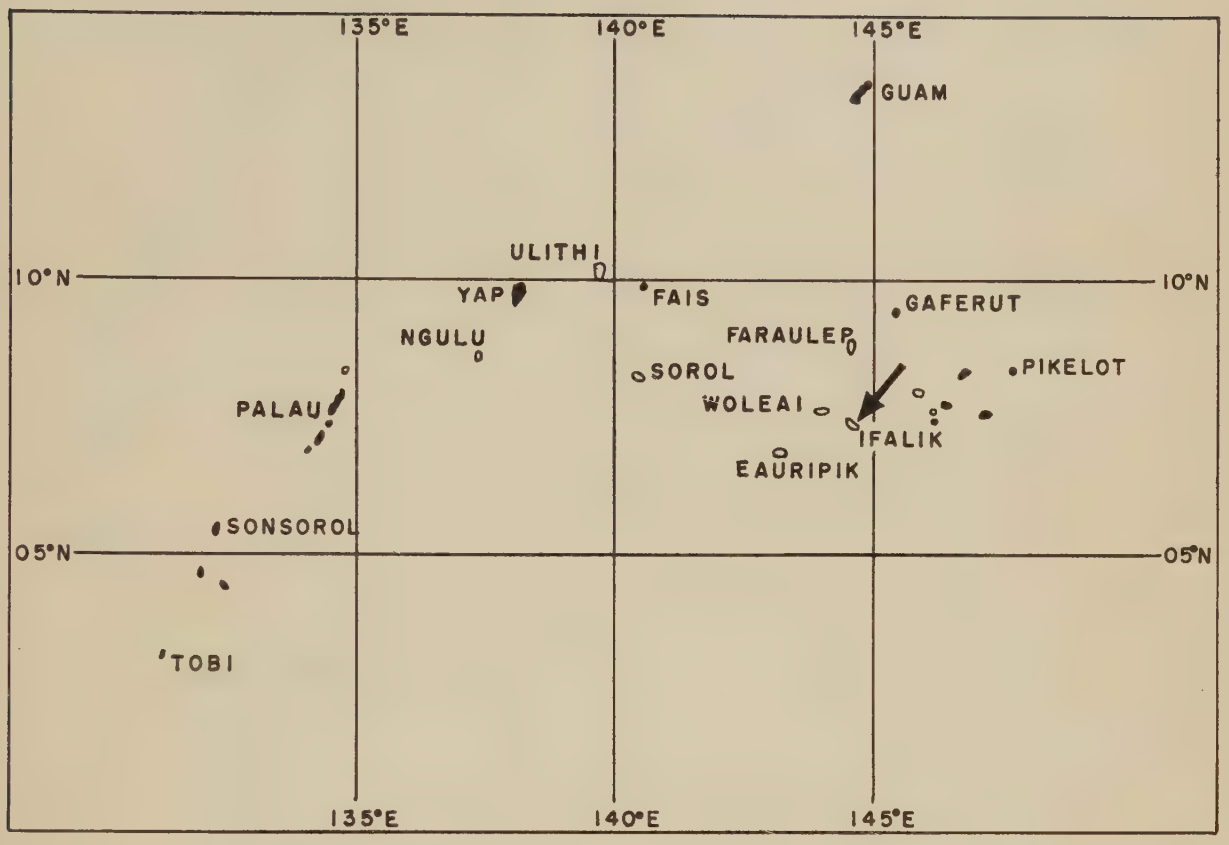
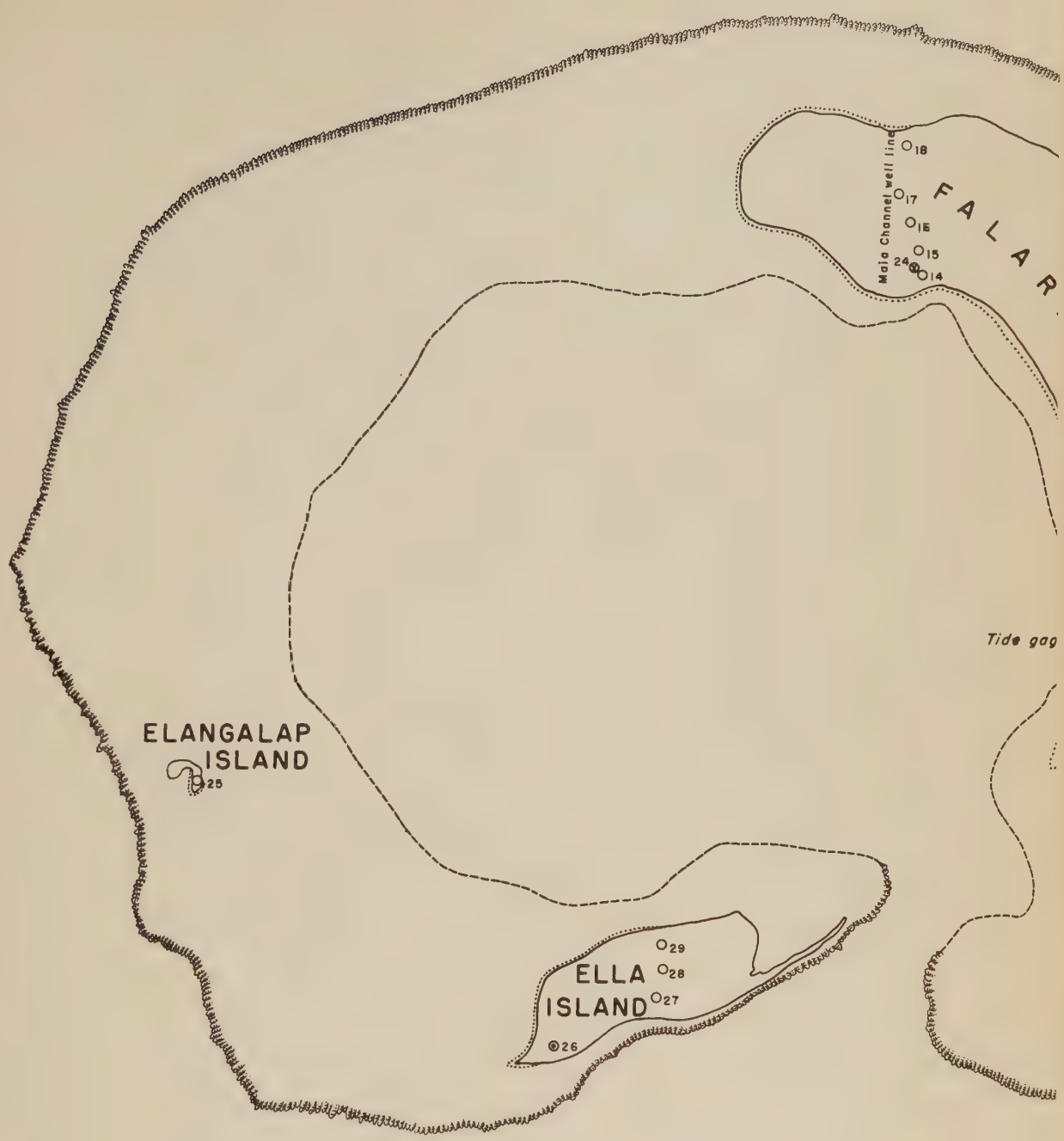


Figure 1.– Outline map of the Western Caroline Islands.



EXPLANATION

	Ocean reef.
	Lagoonal reef.
	Sand beaches.
	Vegetation line on Island.
O_{18}	Well.
$\otimes_{24}$	Retting pit.
$\odot_{26}$	Pond.
$\bullet_{2}$	Sampling point in taro pit.
$\times_{23}$	Sampling point in mangrove swamp.

IFALIK AT

(Traced from uncontrolled a

0 0.5

0 1000 2000 3

Approximate Sca

LL

ial mosaic)

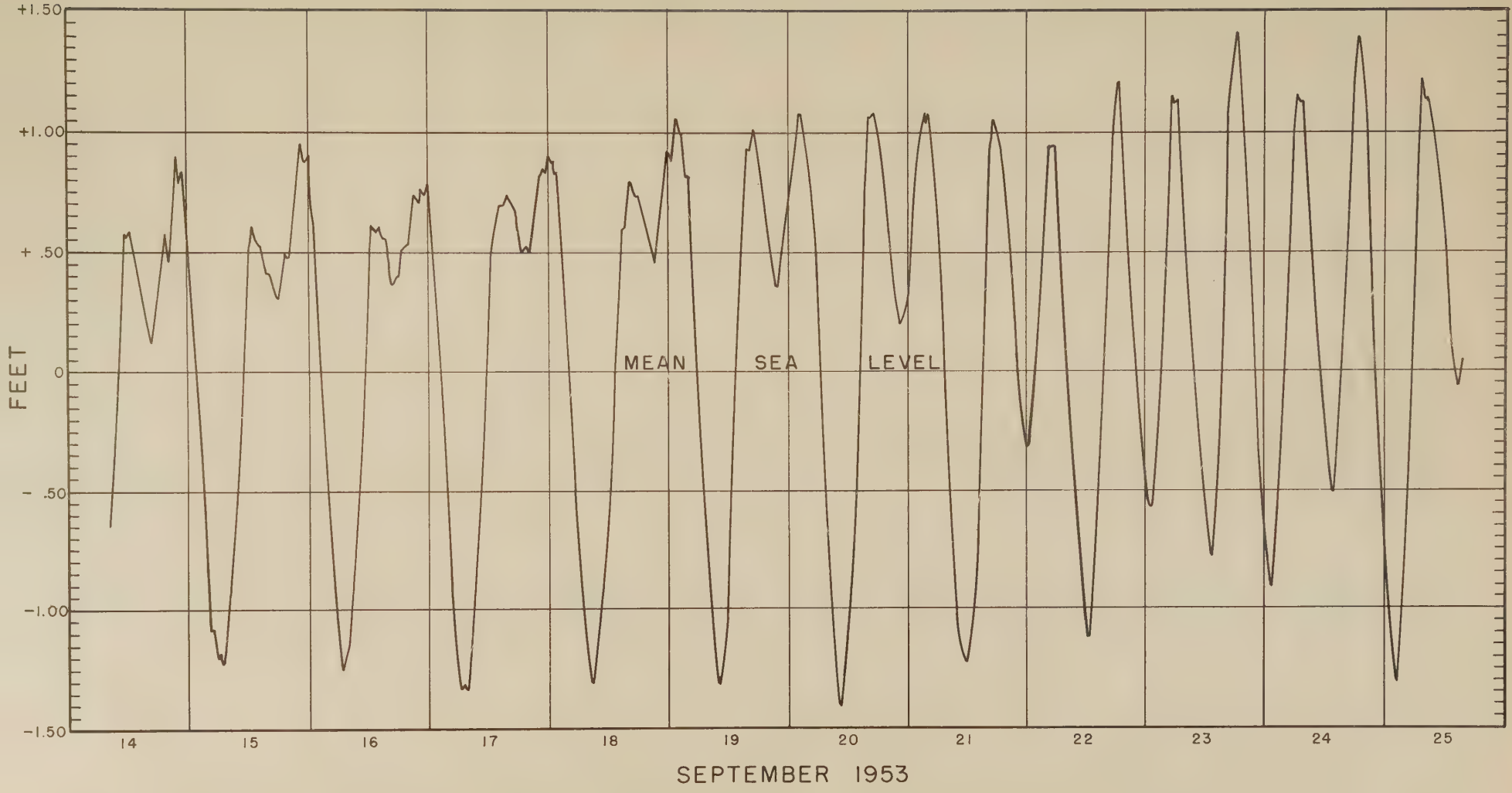


Figure 3.- Tidal graph in lagoon at Ifalik Atoll, September 14-25, 1953.

Table 1.--Rainfall at Ifalik Atoll, 1953, in inches

Day	July	August	September	October	November
1	0	0.24	0.30	0.01	0.18
2	.54	.15	.16	.55	2.03
3	.34	1.90	0	.02	--
4	.12	.54	.19	.12	1.35 1/
5	.20	.18	0	.14	.01
6	0	.95	.74	T	T
7	0	.05	.02	0	.03
8	T	2.55	.39	.10	.05
9	T	3.20	0	.13	
10	.02	.81	.15	.28	
11	.02	1.15	.13	--	
12	.20	.11	--	.84 1/	
13	.25	.25	1.97 1/	.53	
14	.08	.61	.76	.01	
15	0	.50	.91	.70	
16	2.98	1.06	.54	.40	
17	.68	0	.15	.01	
18	1.44	0	2.70	.92	
19	.24	0	1.03	.99	
20	.16	.02	.40	.24	
21	.16	.33	.09	.35	
22	.30	.15	.12	0	
23	0	1.67	0	.32	
24	.05	0	--	.04	
25	.32	0	.87 1/	.51	
26	0	.59	.11	--	
27	.05	.25	T	.13 1/	
28	.11	1.16	0	.47	
29	.10	.09	.25	3.56	
30	.30	0	0	.02	
31	.06	0		0	
TOTAL	8.72	18.51	11.98	11.39	

1/ 48-hour reading.

Table 2.--Atmospheric pressure at Ifalik Atoll, 1953, in millibars observed between 0800 and 0900 hours

Day	July	August	September	October
1	--	1008	1008	1010.5
2	--	1009	1008	1010.5
3	1009	1009	1008.5	1010
4	1009	1007.5	1008.5	1010
5	1010	1009	1009	1009
6	1010	1009	1010	1009.5
7	1010.5	1009	1010	1009
8	1011	1006.5	1008	1009
9	1010	1007.5	1008.5	1008
10	1009	1006	1009	1010
11	1010	1008	1008	--
12	1010	1007	--	1008
13	1010	1008	--	1007
14	1009	1007	1008.5	1006
15	1008	1007	1008.5	1006
16	1008	1008	1008.5	1007
17	1009	1009	1008.5	1007
18	1008	1009	1006	1007
19	1008	1009	1005.5	1007
20	1007.5	1009	1007	1008
21	1007	1008	1008.5	1009
22	1009	1007	1009	1008
23	1007.5	1006	1008	1007
24	1008	1006.5	--	1008
25	1008	1006	1008.5	1009
26	1008	1005	1009.5	--
27	1006	1004	1009.5	1007.5
28	1007	1006	1009.5	1008.5
29	1007.5	1008	1010	1008
30	1007.5	1008	1010	1008
31	1007	1008.5	--	1008

Table 3.--Relative humidity at Ifalik Atoll, 1953, in percent observed between 0800 and 0900 hours

Day	July	August	September	October
1	84	88	87	89
2	88	90	85	96
3	92	100	85	78
4	95	81	90	95
5	90	84	78	92
6	84	85	85	84
7	84	86	81	85
8	84	88	82	82
9	83	100	92	85
10	84	88	82	95
11	92	98	81	--
12	85	83	--	85
13	81	91	93	89
14	84	85	85	82
15	100	90	100	78
16	95	83	83	78
17	100	81	89	80
18	89	85	96	82
19	92	84	91	86
20	82	82	96	84
21	89	88	91	82
22	89	89	82	82
23	85	85	80	--
24	85	86	--	--
25	90	81	85	--
26	79	82	87	--
27	80	81	77	--
28	79	88	88	--
29	85	93	81	--
30	100	85	85	--
31	83	83	--	--

Table 4.--Air-temperature data at Falarik Island, Ifalik Atoll, 1953
Maximum and minimum measurements in degrees Fahrenheit.
All measurements made in the school building

Day	July		August		September		October	
1	--	--	91	76	90	77	91	79
2	86	76	90	77	90	80	88	75
3	87	76	88	74	90	80	87	77
4	89	76	84	73	90	76	91	77
5	87	76	82	75	89	77	90	77
6	90	77	82	76	88	75	89	78
7	88	77	82	77	85	77	90	78
8	90	78	86	75	88	78	90	78
9	90	78	80	74	91	76	90	77
10	88	77	82	74	88	76	90	77
11	90	76	84	74	86	76	--	--
12	89	78	84	76	--	--	90	75
13	89	77	87	78	90	76	88	76
14	89	78	88	76	86	76	87	79
15	90	75	82	76	89	74	--	--
16	80	73	83	74	84	74	84	77
17	88	76	88	78	87	76	87	80
18	81	73	86	77	88	73	85	86
19	88	75	89	76	82	75	87	76
20	82	76	89	77	86	76	86	76
21	88	77	88	77	84	76	87	77
22	89	76	88	77	--	76	87	78
23	85	78	86	75	89	79	89	75
24	86	76	86	77	--	--	87	78
25	89	76	85	80	88	77	90	76
26	87	77	88	75	87	77	--	--
27	90	78	88	77	88	77	90	76
28	89	77	85	74	90	77	88	77
29	91	77	88	78	90	76	87	74
30	91	77	87	80	91	78	82	77
31	88	78	90	78	--	--	86	79

feet west of the west end of the Fan Nap, which is the chief's clubhouse. The altitude of the "X" is 3.57 feet above mean sea level as determined from the tide data.

Tide data were not obtained for the ocean. A comparison was made between the tide data obtained in the lagoon and the predicted ocean tides as published by the Coast and Geodetic Survey for Woleai Atoll, which is about 45 miles from Ifalik. No direct correlation was observed, other than that the observed tide in the lagoon preceded the predicted tide in the ocean 90 percent of the time. The averaged calculated precedence of the lagoon tides was 45 minutes and the maximum precedence was 1 hour 48 minutes. This order of sequence is a reversal of what would normally be expected, and at present no explanation can be offered other than possibly that the actual tides in the open ocean at Ifalik are considerably different from the predicted tides.

WATER SUPPLY

Rainwater

There is practically no artificial catchment of rainwater on Ifalik. Only two catchment systems were observed, each consisting of an oil drum receiving water from the trunk of a palm tree. One provided a household with water for cooking and the other supplied water to irrigate half a dozen puny tobacco plants which were being carefully nurtured to alleviate the island's tobacco shortage.

Three sample of rainwater were obtained for analysis, one from the rain gage, the second from catchment on the roof of a canvas tent, and the third from a drum fed by catchment on a palm tree. The sample from the rain gage had a chloride content of 5 parts per million (ppm) and a hardness of 12 ppm. The sample from the tent had a chloride content of 10 ppm and a hardness of 10 ppm. The sample from the drum had a chloride content of 52 ppm and a total hardness of 36 ppm. The sample from the drum had a higher salt content than those from the gage and the tent because, in the course of running through the crown of the tree and down the trunk, the water presumably had greater opportunity to dissolve salt crystals blown in by the wind from the ocean.

Ground Water

Occurrence.--The only source of fresh water on any island in Ifalik Atoll is the rain that falls directly on that island. Part of the rainfall evaporates or is transpired by plants, and the remainder, because of the high permeability of the island sediments, seeps directly into the ground. There is no significant surface runoff. The fresh water, which is only about 40/41 as heavy as salt water, floats on the surface of the salt water

roughly in the shape of a dome, the edges of which coincide approximately with the edges of the island. The fresh water displaces a volume of salt water equal to its own weight and depresses the fresh-salt-water interface below sea level under the island. Under ideal conditions in a homogeneous island, because of the 40/41 weight relationship of fresh to salt water, for every foot the water table is above sea level the interface is about 40 feet below sea level. Actually the shape of the fresh-water body varies, depending upon local geologic conditions and variations in rainfall, and the 40-to-1 depth ratio is modified by a transition zone of variable thickness in which there is a mixture of fresh and salt water. This double-convex fresh-water body floating on sea water is known as the Ghyben-Herzberg lens. It is the only source of potable ground water in Ifalik and is tapped by means of shallow dug wells.

Three lines of wells for ground-water observations were established on Falarik Island - the Fan Nap line, the Fan Ni Wa line, and the Maia Channel line, as shown in figure 2. Benchmarks for determination of altitudes of water levels at 15 of the wells were tied in with mean sea level as determined by the tide gage. The surveying was done with a telescopic alidade, but because of difficulty with the instrument some of the water-level determinations may be inaccurate by several tenths of a foot. Water-level measurements were made on Falarik Island only. Wells on the other islands were used only for sampling purposes.

Continuous measurements of water levels by means of a Stevens type-F recorder were made at nine wells on Falarik Island. The length of observation at each well was 1 day (figure 4 shows a representative day's record), and the mean water levels determined at each well by the day's observation are shown in figure 5. The value of the mean water levels is somewhat doubtful because records of water levels in the wells were obtained on separate days during the rainy season over a period of 11 days, during which more than 7 inches of rain fell. The effect of rainfall on the water level in each well was variable and depended on the day during the 11-day period on which the well was measured. The mean water levels, therefore, are not completely comparable and also probably are not representative of the means that would be determined if measurements were made over a period of time long enough to average seasonal fluctuations. The configuration of the ground-water body as determined by the water-level measurements does not agree with the configuration suggested by chloride determinations, which are discussed in the next section of this report. The chloride data are believed to be more reliable.

The mean water levels, however, do give an indication of the thickness of the Ghyben-Herzberg lens on Falarik. Even allowing for errors due to surveying and shortness of record, the lens on Ifalik undoubtedly attains a head of at least 1 foot and possibly 1-1/4 feet above mean sea level. The depth to salt water below mean sea level, therefore, probably is 40 feet or more. The area of maximum thickness in general is in the center of the island or on the lagoon side of the center and from there the thickness of the lens diminishes to zero at both shorelines. The 40-foot figure is a

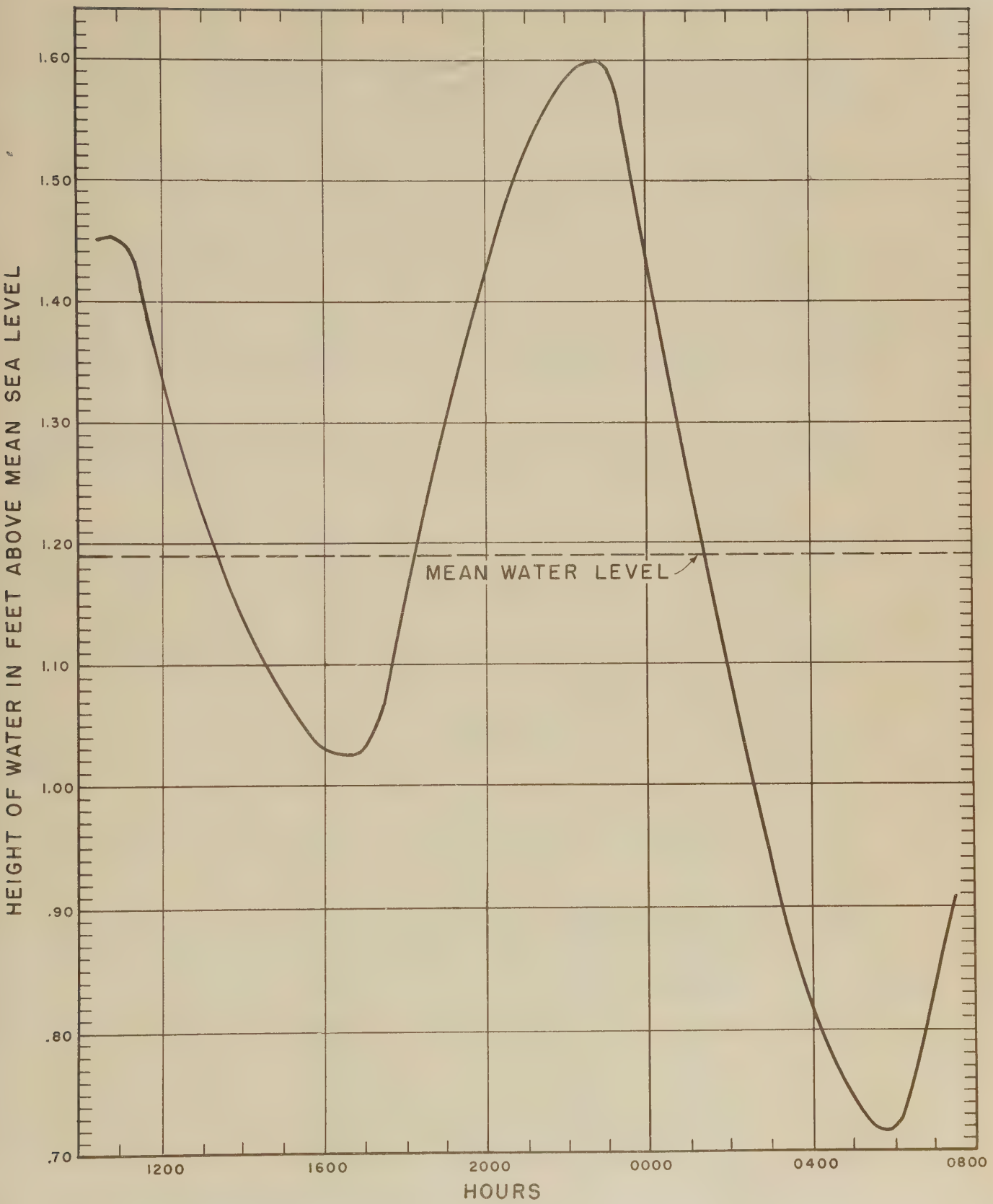


Figure 4.- Hydrograph for well 6, Ifalik Atoll.

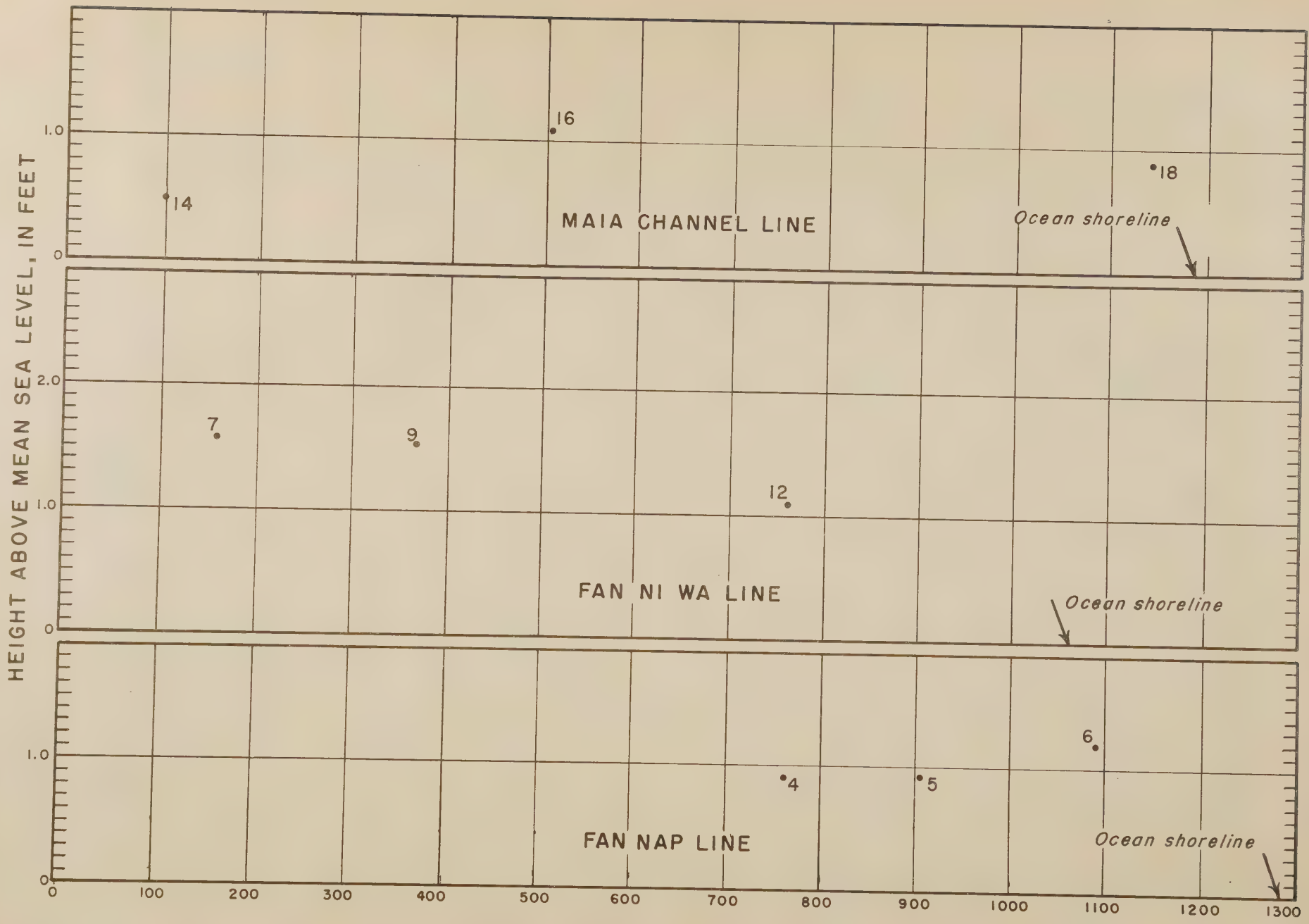


Figure 5. – Mean water levels in wells, Falarik Island, Ifalik Atoll.

wet-season figure, and the depth undoubtedly decreases during normal dry seasons and during extended periods of drought. Native informants state that they have no recollection of a drought on Ifalik. It is assumed, therefore, that the lenses on Falarik and Falalap have never shrunk to the point where food plants or well-water supply have been noticeably affected.

The amount of damping and lag of the tides as they move through Falarik Island is shown in figures 6 and 7 by a comparison of the tidal curve obtained in the lagoon and the tidal fluctuations of the water table observed in wells on Falarik. The data for each well were obtained by means of continuous observations over a period of 1 day. Both the damping and lag increase progressively from the lagoon shore toward the ocean shore. The full significance of this progressive change cannot be completely explained because of the lack of tidal data from the ocean side of the island. If such data were integrated with the tidal data obtained in the lagoon, a significant change might result in the slope of the curves shown in figures 6 and 7.

The Ghyben-Herzberg lens is incompletely developed on Ella Island and apparently not developed at all on Elangalap Island. These islands are discussed more fully in the section on Quality of water.

Quality.--The extent of development of the Ghyben-Herzberg lens controls the quality of the ground water in the islands in Ifalik Atoll. The lens is well developed in Falarik and Falalap Islands.

The three lines of wells on Falarik Island were sampled on September 21, 1953, and again during the period November 1 - 3. Partial chemical analyses were made for all samples and the results are shown in table 5. The relation of chloride content to distance from the shore is shown in figure 8 for the samples obtained on September 21, and in figure 9 for the samples obtained November 1 - 3. The chloride content of the water along the Fan Nap and Maia Channel lines is greatest near the ocean shore, decreases to a minimum about two-thirds of the way across the island, and rises again near the lagoon shore. These relationships suggest that the Ghyben-Herzberg lens has its thickest development about one-third of the way inland from the lagoon shore and from there thins toward both shores. The displacement of the point of maximum development of the lens from the center of the island toward the lagoon shore could be the result of high permeability in the rocks on the ocean side. The chloride content of the water along the Fan Ni Wa line of wells suggests that the maximum development of the lens along this line may be nearer the ocean side of the island than it is along the other two lines. If this is so, it may be due to the presence along the ocean shore of well-cemented beach rock which acts as a relatively impermeable barrier which retards the mixing of fresh and salt water that results from tidal fluctuations. The beach rock is not exposed throughout, but according to J. I. Tracey, personal communication (1954) it probably extends along most of the northeast coast of Falarik. It terminates, however, before reaching the Fan Nap and Maia Channel well lines.

Table 5.--Partial chemical analyses (ppm) and temperature (°F) of water from various sources in Ifalik Atoll
(Field determinations by Ted Arnow)

No.	Source	Date (1953)	Chloride	Total hardness as $CaCO_3$	Calcium hardness as $CaCO_3$	Temperature
	Falarik Island					
1	Shallow pond, 30 feet in diameter	Sept. 21	28	240	132	79.5
		Nov. 1	35	210	129	--
2	Taro pit	Sept. 21	12	290	242	79.5
3	Dug well	Sept. 21	16	100	71	77.5
		Nov. 1	5	170	88	--
4	do.	Sept. 21	52	170	132	79
		Nov. 3	5	100	82	---
5	do.	Sept. 21	44	230	181	--
		Nov. 1	55	190	132	--
6	do.	Sept. 21	84	250	132	79
		Nov. 1	95	210	66	--
7	do.	Sept. 21	48	320	275	79
		Nov. 1	50	320	269	--
8	do.	Sept. 21	8	220	170	76
9	do.	Sept. 21	8	140	132	77
		Nov. 1	20	220	170	--
10	Taro pit	Sept. 21	10	--	--	79
11	Dug well	Sept. 21	6	210	93	78
		Nov. 1	10	120	104	--
12	do.	Sept. 18	8	140	93	78
		Nov. 1	25	170	132	--
13	do.	Sept. 21	14	120	93	79
		Nov. 3	40	340	286	--
14	do.	Sept. 21	28	290	192	79.5
		Nov. 1	35	190	104	--
15	do.	Sept. 21	16	240	187	80
		Nov. 1	15	210	176	--
16	do.	Sept. 21	24	240	105	81
		Nov. 1	27	160	124	--
17	do.	Sept. 21	44	220	165	79
		Nov. 1	35	230	165	--

Table 5.--Partial chemical analyses (ppm) and temperature (°F) of water from various sources in Ifalik Atoll--Continued

No.	Source	Date (1953)	Chloride	Total hardness as $CaCO_3$	Calcium hardness as $CaCO_3$	Temperature
18	Dug well	Sept. 21	68	290	132	80
		Nov. 1	1,160	660	242	--
24	Coconut retting pit	Sept. 21	28	340	302	--
-	Rain sample from canvas tent	Sept. 18	10	10	7	--
-	Rain sample from palm tree	Sept. 26	52	36	17	--
-	Rain sample from rain gage	Sept. 26	5	12	9	--
	Falalap Island					
19	Dug well	Sept. 21	252	390	215	--
		Nov. 3	445	400	247	--
20	Taro swamp	Sept. 21	12	170	148	--
21	Dug well	Sept. 21	40	180	121	--
		Nov. 3	10	110	104	--
22	Taro swamp	Sept. 21	16	140	71	--
23	Mangrove swamp	Sept. 21	5,500	2,020	462	--
30	Shallow pond, 12 by 25 feet	Sept. 21	24	200	132	--
31	Dug well	Sept. 23	44	320	247	--
32	do.	Sept. 23	32	270	198	--
33	do.	Sept. 23	20	280	264	--
34	do.	Sept. 23	48	280	214	81
	Ella Island					
26	Shallow pond, 50 by 350 feet	Sept. 20	10,200	4,100	660	--
27	Dug well	Sept. 20	108	230	170	--
		Nov. 4	80	210	165	--
28	do.	Sept. 20	1,090	1,090	330	--
		Nov. 4	3,060	1,270	407	--
29	do.	Sept. 20	204	280	181	79
		Nov. 4	180	250	176	--
	Elangalap Island					
25	Dug well	Sept. 20	10,900	3,920	616	--
		Nov. 4	15,000	3,800	616	--

The chloride content of the ground water throughout Falarik Island rose slightly between the two periods of sampling, but the only significant change was at well 18, where the chloride content rose from 68 to 1,160 ppm. This sharp rise indicates that the lens is thinner in the vicinity of well 18 than elsewhere along the three lines of wells. According to native informants, the northwest corner of Falarik Island was once separated from the remainder of the island by a narrow channel. The channel was filled during a typhoon early in the 20th century and is now marked by the Maia Channel line of wells. Well 18, however, is east of the filled channel which, north of well 17, curves toward the northwest (J. I. Tracey, personal communication). According to Tracey, well 18 is in bedded sands and gravels that are typical of bar or beach deposits. These deposits are very permeable and permit free movement of water during the tidal cycle. The high permeability coupled with the fact that the shoreline is only 110 feet away may well explain the poor development of the fresh-water lens in the vicinity of well 18.

The relation of total hardness of the ground water to distance from the shoreline for the three lines of wells on Falarik in general follows the same pattern observed for the chloride data (fig. 10). Because of the acid environment created by decaying vegetation, sampling points 2 and 24, a small taro pit and a coconut retting pit, yield water harder than that of nearby wells.

In addition to the partial analyses discussed above, a set of water samples from the Fan Ni Wa line was analyzed for all major dissolved constituents (see table 6). The results in general agree with those discussed above. The only significant departure from what would generally be expected in the composition of ground water from a coralline atoll is the high silica content, which in four of the six wells exceeded that of sea water. The source of the excess silica may possibly be a concentration of sponge spicules or large amounts of drift pumice.

Analyses of water samples obtained on Falalap Island indicate that the Ghyben-Herzberg lens is as well developed there as it is on Falarik Island. Much of the central part of the island is a fresh-water swamp (see samples 20 and 22 in table 5), but closer to the coasts where boulder ramparts exist the ground water becomes more saline as the lens becomes thinner (see sample 19 in table 5). The northwest coast of Falalap, however, is formed by finer grained sediments which are conducive to the formation of a well-developed Ghyben-Herzberg lens. Samples from wells 30 to 34, which are 125 to 180 feet from the coast, all showed less than 50 ppm of chloride. The fresh-water lens in Falalap Island is disrupted along the ocean shore by brackish or saline areas in which mangrove trees grow. A ground-water sample obtained from one such mangrove swamp (see sample 23 in table 5) had a saline content approximately one-third that of sea water.

Three wells were dug on Ella Island along a line where the island is approximately 700 feet wide (fig. 2). The two outer wells, numbers 27 and

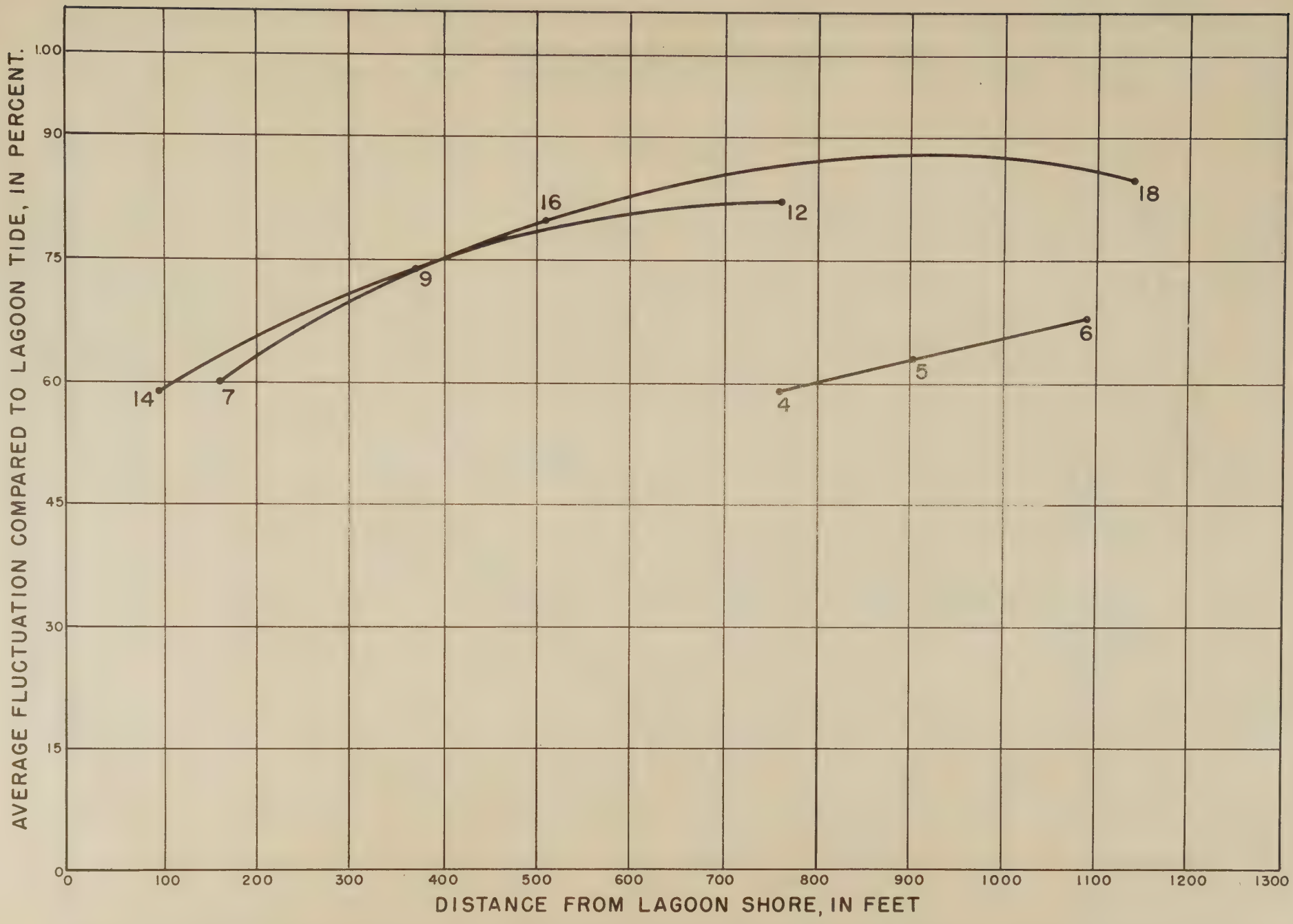


Figure 6.— Relation of damping of tidal fluctuations in wells to distance of wells from shoreline, Falarik Island, Ifalik Atoll.

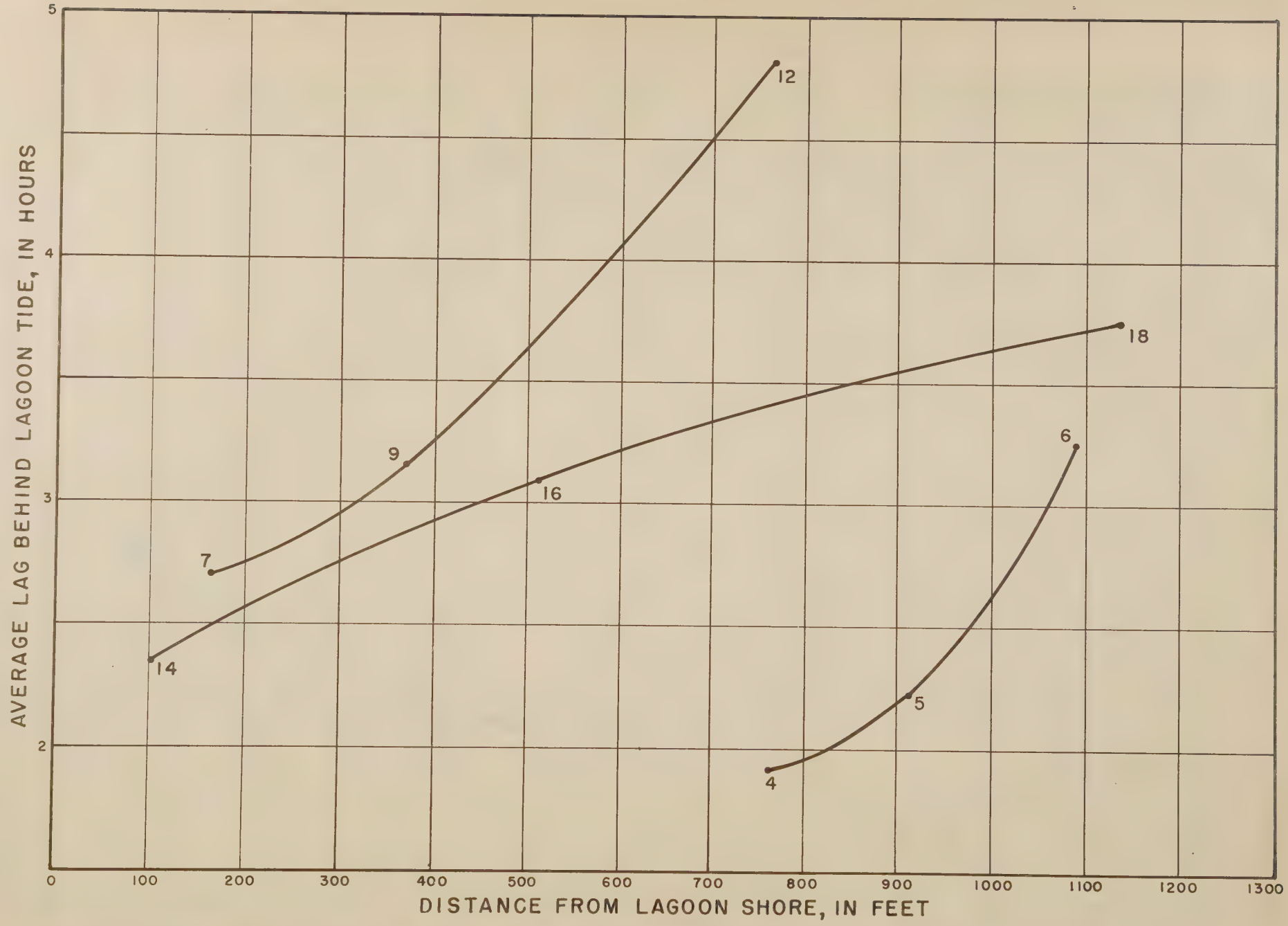


Figure 7.— Relation of lag of tidal fluctuations in wells to distance of wells from shore line, Falarik Island, Ifalik Atoll.

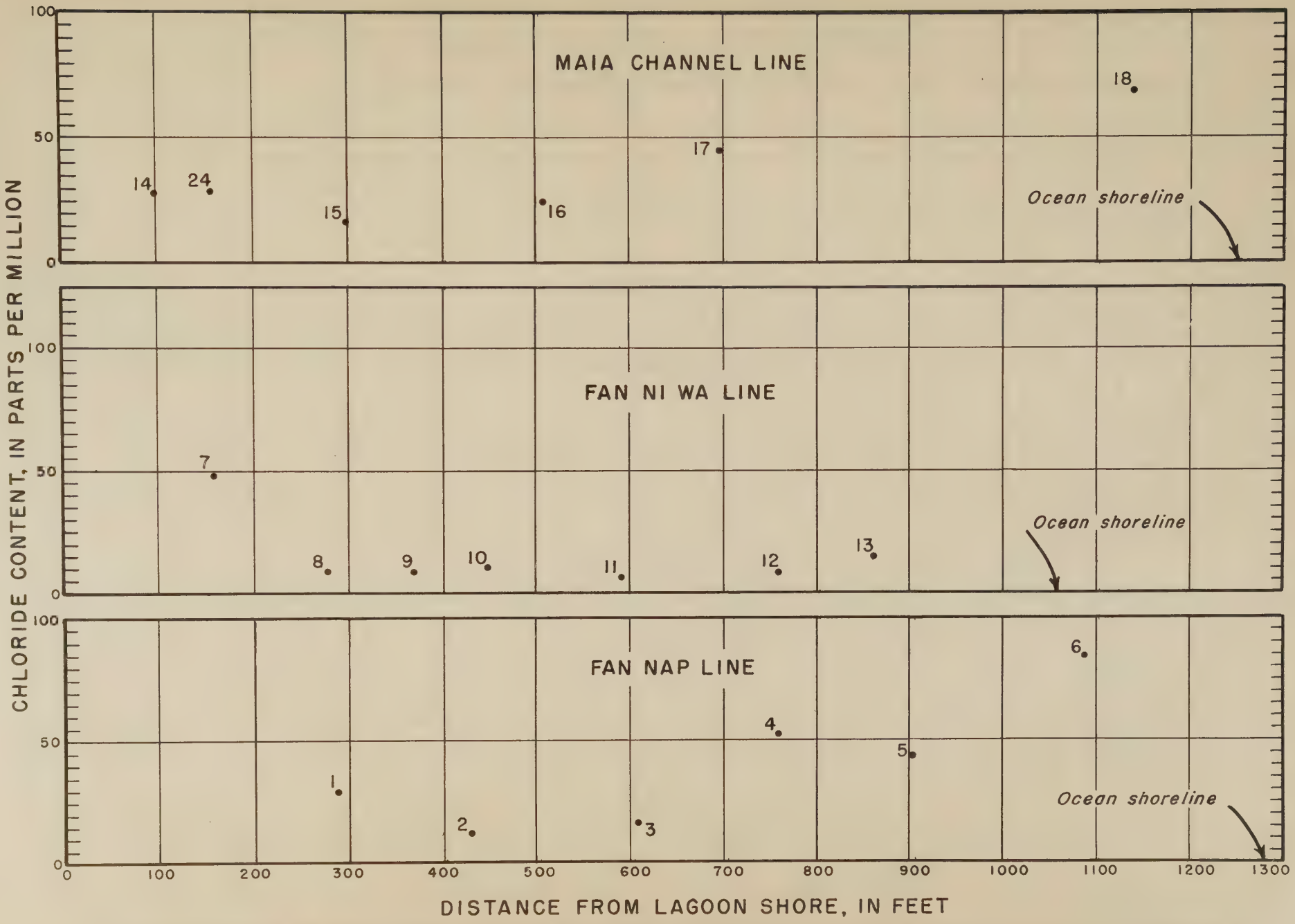


Figure 8.— Relation of chloride content of ground water to distance from shore, Falarik Island, Ifalik Atoll, September 21, 1953.

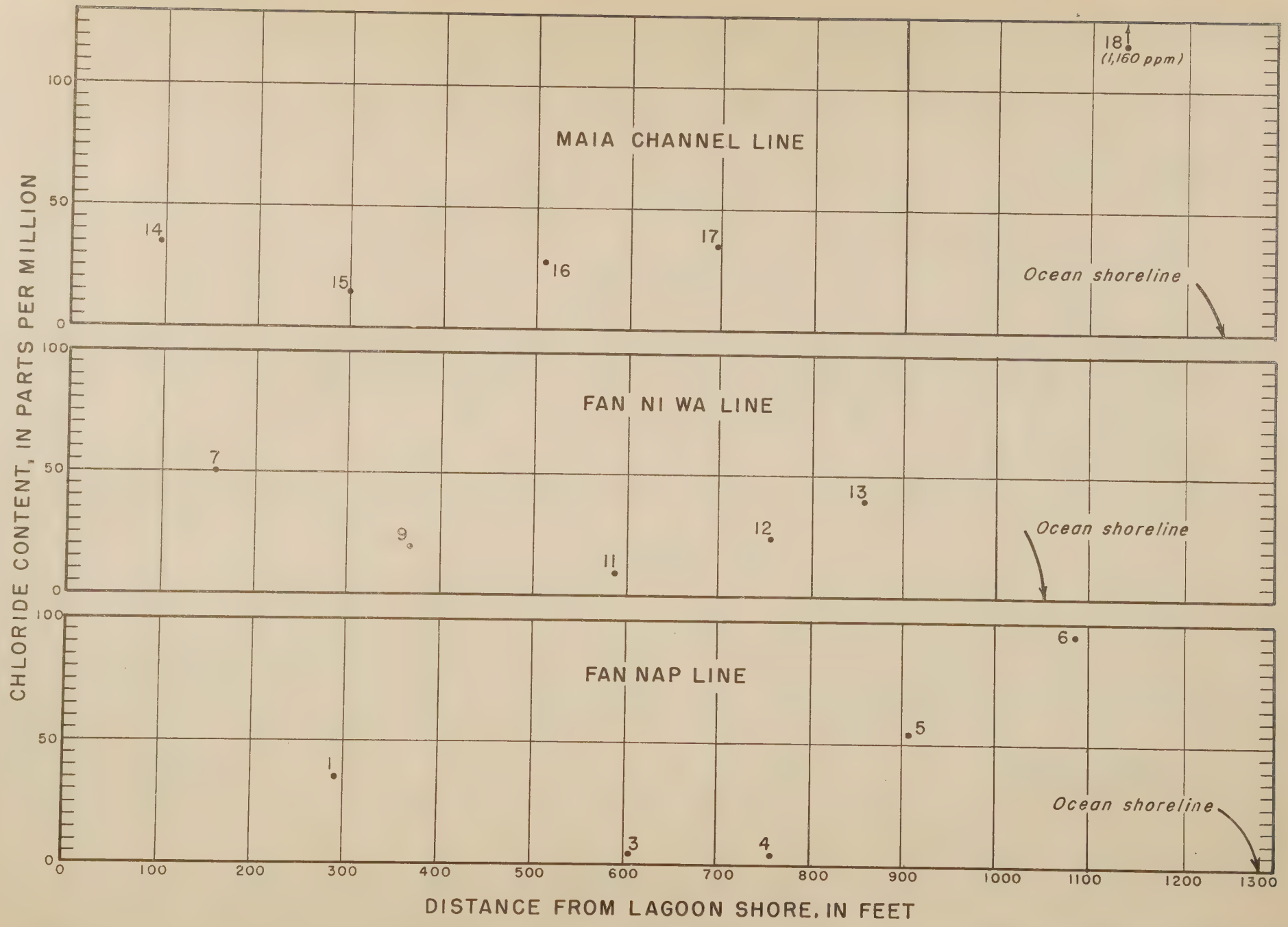


Figure 9.— Relation of chloride content of ground water to distance from shore, Falarik Island, Ifalik Atoll, November 1-3, 1953

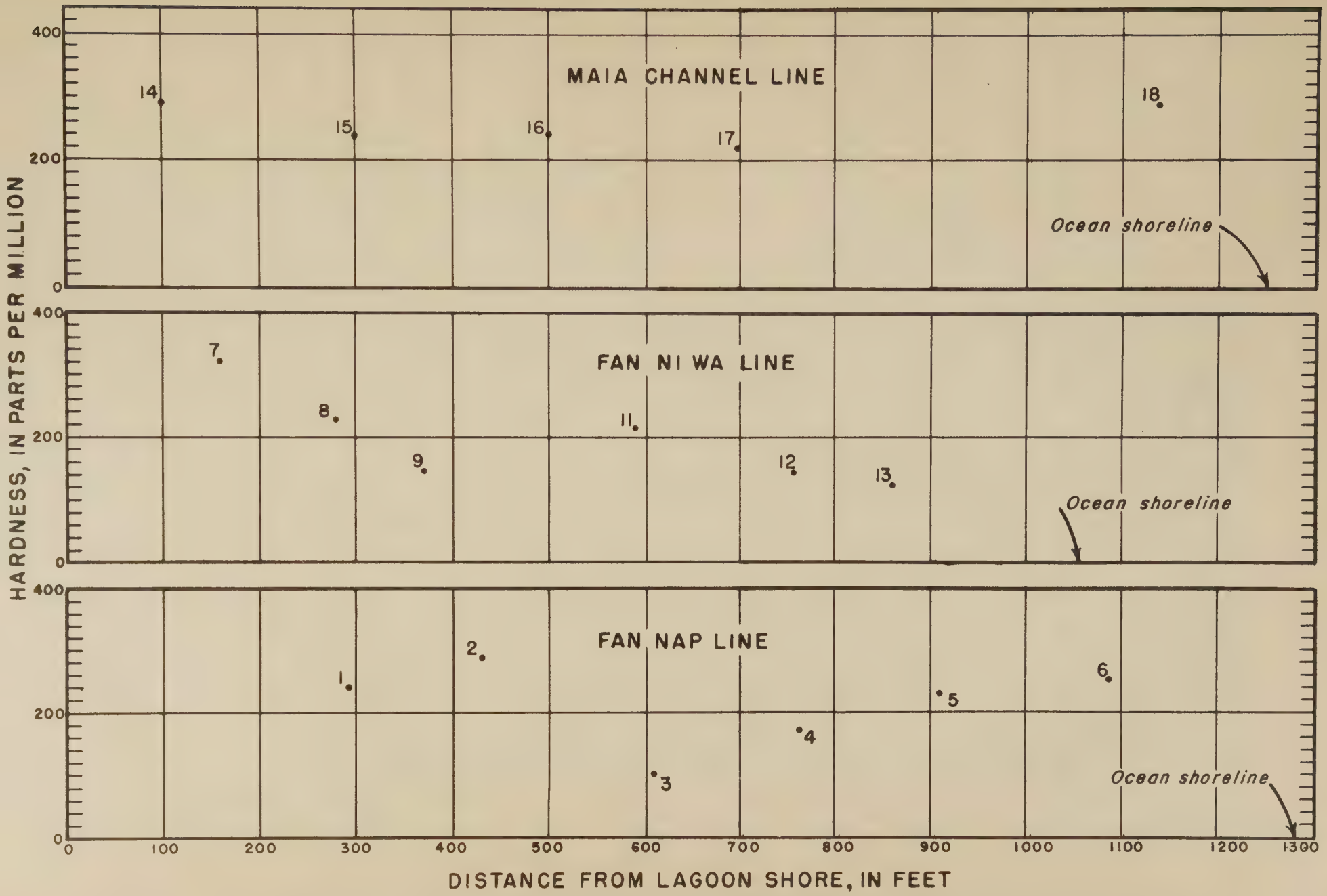


Figure 10.— Relation of hardness of ground water to distance from shore, Falarik Island, Ifalik Atoll, September 21, 1953.

Table 6.--Chemical analyses of water samples (ppm) from Fan Ni Wa well line, Ifalik Atoll
Analyses by U. S. Geological Survey, Quality of Water Branch

Well number	Well 7	Well 8	Well 9	Well 11	Well 12	Well 13
Date of collection	9/23/53	9/23/53	9/23/53	9/23/53	9/23/53	9/23/53
Dissolved solids	446	271	232	157	233	174
Specific conductance (micromhos at 25°C)	748	467	290	272	399	311
Hardness (as $CaCO_3$)	331	242	204	134	172	132
Non-carbonate hardness (as $CaCO_3$)	0	0	10	8	13	0
Silica (SiO_2)	15	8.8	13	4.0	9.5	3.6
Iron (Fe)	.17	.37	.06	.03	.07	.03
Calcium (Ca)	103	82	68	47	59	44
Magnesium (Mg)	18	9.2	8.3	4.1	6.0	5.4
Sodium (Na)	29	4.7	5.8	3.9	15	12
Potassium (K)	8.3	1.7	3.0	.4	1.7	2.5
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	408	298	237	154	194	163
Sulfate (SO_4)	5.8	3.5	4.1	2.6	8.7	7.7
Chloride (Cl)	47	6	10	5	26	14
Fluoride (F)	.2	.3	.4	.5	.5	.2
Nitrate (NO_3)	.6	.5	.2	3.8	.3	.6

29, which are about 175 feet from the ocean and lagoon shores respectively, contain fresh water, whereas, oddly enough, the middle well, number 28, contains water averaging about 2,000 ppm in chloride. (See table 5.) The higher salinity at well 28 may be due to the presence of a section of underlying reef which has a more permeable matrix or a larger number of cracks than the sections of reef underlying wells 27 and 29. The greater tidal mixing would permit the development of a thicker zone of mixture within the Ghyben-Herzberg lens. Presumably at well 28 the edges of the zone of mixture extend to the water table. The lens is practically undeveloped in the southwest end of Ella Island where the land is only about 350 feet wide. There a shallow ground-water pond, with dimensions of about 50 by 350 feet, has salinity greater than half that of sea water (see sample 26 in table 5).

Elangalap Island is divided into two roughly equal segments which are independent hydrologic units. The larger segment has maximum dimensions of about 75 by 150 feet and an area of 0.0004 square mile. It does not support a fresh-water lens. Two samples obtained from a well in the center of that land unit ranged in chloride content from 60 to 80 percent of that of sea water (see sample 25 in table 5).

The temperature of the ground water at Ifalik ranged from 76° to 81° Fahrenheit and averaged 79° Fahrenheit.

Use of Water

Ground water is used by the people on Ifalik for drinking, cooking, and washing. Bathing is done in the lagoon or in wells. The ground water is obtained from shallow dug wells which, for the most part, are uncased and uncurbed. Several wells which are reserved for drinking and cooking purposes have wooden covers and curbs and are cased with limestone blocks. Practically no rainwater is caught or used directly. This is in contrast to the Marshall Islands, where the people prefer rainwater to well water for all purposes (Cox, 1951; Arnow, 1954).

Ground water is equally important to the people of the atoll through its control of vegetation. The existence of extremely fresh ground water permits the growth of taro and breadfruit in widespread areas in Falarik and Falalap. Breadfruit will not grow successfully in certain parts of Falarik - notably in the filled Maia Channel and along a narrow strip of gravelly sand which parallels the lagoon shore and expands to cover about half of the southwest corner of the island. The ground water underlying these areas is fresh however, and the failure of the breadfruit is apparently due to a soil deficiency. The explanation offered by the people of Ifalik is that not enough "brown soil" is present.

The coconut palm, the backbone of the Ifalikian way of life, grows successfully almost wherever planted on the three larger islands in Ifalik and is even found on tiny Elangalap. There is no fresh-water lens in Elangalap, but because of the heavy rainfall the palms evidently obtain sufficient fresh water directly from the zone of soil moisture.

SELECTED REFERENCES

Arnow, Ted, 1954, The hydrology of the northern Marshall Islands: Atoll Research Bull. 30.

Bryan, E. H., Jr., 1946, A geographic summary of Micronesia and notes on the climate of Micronesia: U. S. Commercial Company Econ. Survey (unpublished).

Burrows, E. G. and Spiro, M. E., 1953, An atoll culture: Human Relations Area Files.

Cox, D. C., 1951, The hydrology of Arno Atoll, Marshall Islands: Atoll Research Bull. 8.

U. S. Navy, 1948, Handbook on the Trust Territory of the Pacific Islands; Navy Department, Washington, D. C.

Wentworth, C. K., 1947, Factors in the behavior of ground water in a Ghyben-Herzberg system: Pacific Sci., v. 1, p. 172-184.

ATOLL RESEARCH BULLETIN

No. 45

A partial list of the plants of the Midway Islands

by

Johnson A. Neff and Philip A. DuMont

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences--National Research Council

Washington, D. C.

August 15, 1955

A partial list of the plants of the Midway Islands

by

Johnson A. Neff and Philip A. DuMont

The Midway Islands, 1,300 statue miles northwesterly from Honolulu and only 56 miles southeast of Ocean Island, the end of the Leeward chain, are known to tens of thousands of Americans. Sand Island, the larger of the two, was an operating base for Pan-American Airways from 1935 to 1950. It has been an east-bound refueling stop for Armed Forces trasnport planes since the end of World War II. During one stage of the hostilities the 1,282 acres of the two islands held more than 15,000 fighting men, their equipment, housing, shops and warehouses. Sand Island, too, has long been an active U. S. Navy base.

The Midway Islands were discovered in 1859 when Captain W. C. Brooks took possession of them from the U. S. Government. Being very near the exact center of the north Pacific they were termed the Midway Islands, or just Midway. Eastern Island, the older of the two geologically, covers 334 acres and is composed of broken coral, shells and coarse sand. Sand Island, 948 acres, is made up largely of white coral sand. Except for a survey in 1867 by personnel from the U.S.S. Lackawanna, only shipwrecked sailors saw these islands until the Rothschild Expedition visited them in 1891.

Eastern Island has been somewhat vegetated for a much longer period than Sand Island. Photographs taken in 1891 be members of the Rothschild Expedition show fairly dense grass, some Boerhavia and extensive low Scaevola bushes on Eastern, but only a few Scaevola and a few Boerhavia vines on Sand Island.

When the Commercial Pacific Cable Company came to Sand Island in 1902 the island was described as a level waste of glaring white sand with only a few bunches of grass, a few Boerhavia vines and one or two small Scaevola bushes. In 1907 the company planted hundreds of ironwoods, Casuarina, and San Francisco grass, Ammophila, around their coumpound. Within a few years the trees were large enough to protect the northern end of the island from the winter storms and the Scaevola, Boerhavia and Ammophila began to spread. By the beginning of World War II some of the original ironwoods were 70 feet tall and natural re-seeding had spread them over most of Sand Island and even onto Eastern Island.

In the years that followed the original plantings, other plants were introduced, largely close to the Cable Company buildings on the north end of the island. When Pan-American Airways set up their operating base on Sand Island in 1935, a number of plants, largely from Hawaii, were set out near their Gooneyville Lodge. According to Hadden, who was their unofficial gardener from 1936 to 1941, over 200 species of plants were tested on this island. Some of the ornamentals now growing about the residential area of the island were listed in his report of successful introductions, and many of the ornamentals planted about Gooneyville Lodge are still thriving.

During the intervening years, new introductions have occurred as seeds were introduced in packing materials, and as flowers or shrubs were

brought in by resident Navy personnel. We find no record of actual plantings on Eastern Island, but either through man or natural means a number of the plants found on Sand Island are now established on Eastern; in some instances their smaller size indicates their relative youthfulness in this location.

In the autumn of 1954 the authors were assigned by the U. S. Fish and Wildlife Service to study bird problems on the Midway Islands, and were there from November 6 to December 5. Enroute to the islands, while conferring with Mr. E. H. Bryan, Jr., of the Bishop Museum in Honolulu, we learned that the Museum herbarium lacked specimens of many plants known to be growing on Midway. It seemed small repayment for Mr. Bryan's many courtesies that we attempt to add to the Museum's Midway herbarium.

Our objective concerned the bird life of the islands, and plant collecting was entirely a side-line. Plants were picked up during the course of other work so a complete collection was not attempted. We did not search the residential area for flowering plants, nor did we collect specimens of a number of larger ornamentals such as banana, coconut and banyan. At the end of our stay we had transmitted to the Bishop Museum specimens of 48 species of plants. Duplicate specimens of 46 of these were placed in the herbarium of the Wildlife Research Laboratory in Denver. Plant identifications were made by Marie C. Neal of the Museum.

In suggesting a modernized report on the plants of the Midway Islands Dr. Fosberg generously contributed his own notes covering observations made on Sand Island on February 13, 1954. He further abstracted information from two earlier lists of Midway plants (1931, 1935) and furnished a list of principal references on Midway plants.

Neither we nor Dr. Fosberg saw any specimens of a considerable number of the plants listed by these earlier writers. Ecological conditions have changed greatly on the Midway Islands since 1940 when defense preparations were put into high gear there. Some of the earlier species may have passed from the picture, or may now be so restricted in their distribution that we did not encounter them. There has been little attention to gardening on Sand Island since Hadden left there in 1941. Soon after Pearl Harbor military activity on the two islands literally changed the face of the landscape. Bulldozers cleared off the brush and miles of hard-surfaced runways were built. Bulldozers also threw up hundreds of yards of sand revetments and cleared plane parking behind them. Literally hundreds of buildings were scattered all over both islands. Though many of the latter are now falling down, and though Scaevola bush has covered the top of most of the revetments, the mark of wartime activity on the plant ecology of these islands remains clearly visible.

On Eastern Island, slightly more than 100 acres are in runways, buildings, and plane parking strips, to say nothing of the great area of revetments. On Sand Island, more than 200 acres are occupied by the runways, plane parkings, roads, tumbledown wartime buildings, and the residential and administrative area of the active Naval base. Bulldozed areas of ironwoods, Scaevola and other plants that had spread from Cable Company and Pan-American plantings, have in large part been replaced by

apparent later introductions, many of them weed plants.

In the following report of plants that have grown or are now growing on Midway it has been necessary to make use of a series of symbols. C. & C. refers to plants reported by Christophersen and Caum in 1931. St. J. refers to plants listed by St. John in 1935. The symbol FWS refers to observations made by the authors, and FWS-C to those species where specimens were collected by us. FRF refers to plants observed by Dr. Fosberg on February 13, 1954. Comments made are necessarily general, mostly based on our own observations and such notes and records as we made.

Since it is necessary that in such a paper there be but one taxonomic standard, we have followed Dr. Fosberg's recommendations on such matters wherever questions arose. Without the generous assistance of Dr. Fosberg, Mr. E. H. Bryan and Miss Marie Neal of the Bishop Museum, neither this paper nor the collection upon which it is largely based would have been prepared.

Psilotum nudum (L.) Griseb.
C. & C.

Araucaria excelsa R. Br. Norfolk Island pine.
FWS. A few fine specimens are growing in the old Cable Company coumpound area and on the lawns of a few of the officers' quarters, Sand Island.

Pandanus tectorius Park. Screwpine; Hala.
FWS. Occasional specimens occur in the administrative and residential area, two of them at the Administration Building. One was seen in the Scaevola scrub near the south end of Sand Island.

Ammophila arenaria (L.) Link San Francisco grass
C. & C. The planting of San Francisco grass as a soil binder by the Cable Company is reported in every description of the flora of Sand Island. Late in our stay the senior author had not found any grass that seemed to be this species, and spent a number of hours looking for new types; several were collected, but none turned out to be Ammophila.

Cenchrus agrimonoides var. laysanensis F. Br.
C. & C.

Cenchrus echinatus L. Sand bur.
C. & C.; FRF; FWS-C. Locally common, found mostly along the edges of runways, roads and about the larger buildings on Sand and Eastern Islands.

Chloris inflata Link
FRF. FWS-C. Locally common in open spaces on Sand and Eastern Islands.

Cynodon dactylon (L.) Pers. Bermuda grass.
FRF; FWS-C. Abundant. The common lawn grass and spread over much of Sand Island. Locally common on Eastern Island. Now the best sand-binder growing on the islands.

Digitaria ciliaris (Retz.) Koel. Crab grass.
FRF. Dr. Fosberg calls it rare in open sandy areas on Sand Island.

Eleusine indica (L.) Gaertn. Goose grass.
FRF; FWS-C. Locally common, scattered about in open spaces on both Sand and Eastern Islands.

Eragrostis amabilis (L.) W. & A. Love grass.
FRF; FWS-C. Locally common in open spaces on Sand Island. Was not noted on Eastern Island.

Eragrostis variabilis (Gaud.) Steud.
C. & C.; FWS-C. Rare. Found in only two places on Sand Island, one of them a large patch near the terminal.

Eragrostis whitneyi var. caumii Fosberg
C. & C.; FWS-C. Fairly abundant on parts of Sand Island, locally common on Eastern Island. Found growing along edges of runways, and in cracks in runways and plane parking stands.

Lepturus repens (Forst.) R. Br.
C. & C.

Panicum purpurascens Raddi Para grass.
FWS-C. Occasional; found in only two areas on Sand Island, under the ironwoods near the Cable Company compound.

Rhynchelytrum roseum (Nees) Stapf and Hubb. Natal redtop.
FWS-C. Rare, found in only two or three small areas on the older, undisturbed part of Sand Island.

Setaria verticillata (L.) Beauv.
FWS-C. Locally abundant in open spaces on both Sand and Eastern Islands.

Sporobolus virginicus (L.) Kunth
St. J.

Stenotaphrum secundatum (L.) O. Ktze. Buffalo grass.
FRF; FWS-C. Occasional, in open spots in the older vegetated section of Sand Island.

Cyperus alternifolia L. Umbrella plant.
FRF; FWS-C. Two or three densely grown clumps were seen under old ironwoods near the Cable Company compound, a few small plantings about residences, on Sand Island only.

Cyperus javanicus Houtt.
St. J.

Cyperus rotundus L. Nut grass.
FRF; FWS-C. Found locally abundant on both Sand and Eastern Islands, mostly along the margins of runways, along edges of paved roads, and near foundations of larger buildings where run-off of rainfall apparently controls its distribution.

Fimbristylis cymosa R. Br.
FWS-C. Locally common in same general locations as the last, but more restricted in distribution, on both Sand and Eastern Islands.

Cocos nucifera L. Coconut.
FWS. Planted originally by the Cable Company and later by Pan-American, the coconut palms seem to be doing well; on Sand Island only.

Phoenix sp.
FWS. A number of palms of the Phoenix type are to be found on Sand Island among the Cable Company and Pan-American plantings, and on lawns of a few residences.

Commelina diffusa Burm. f. Day flower.
St. J.

Crinum sp.
FRF; FWS. Occasional fine specimens of "spider lilies" may be seen on Sand Island on the lawns of residences and about administrative buildings.

Agave sp. Century plant.
FWS. Occasional plants locally called sisal occur on Sand Island in the residential and administrative area.

Musa sp.
FWS. Some few banana plants were found on Sand Island in the older area near the Cable Company and Pan-American buildings, and an occasional one as an ornamental about a residence. They appear to be surviving but not thriving.

Casuarina equisetifolia L. Ironwood.
FRF; FWS-C. Abundant on both Sand and Eastern Islands. The original plantings appear to have reached maturity and some are dying. Spreading by natural means the ironwoods have scattered all over Sand Island and trees dully 30 feet high were seen on beach-line dunes on the opposite end of the island from the original plantings. A few trees of similar height were found on Eastern Island and small seedlings occur almost all over this island. Within a few years it, too, will very likely be ironwood-covered.

Morus alba L. ? Mulberry.
FRF. Reported by Hadden as growing here; we did not find it but Fosberg located one unhealthy-looking specimen growing in an opening in the scrub on Sand Island.

Ficus retusa L. Chinese banyan.
FWS. A number of banyans of varying size appear to be doing well about the old Cable Company area and about Pan-American's deserted Gooneyville Lodge, on Sand Island.

Coccoloba uvifera (L.) Jacq. Sea grape.
FRF; FWS-C. Not uncommon, single trees growing widely scattered over both Sand and Eastern Islands.

Achyranthes splendens var. reflexa Hbd.
C. & C.

Boerhavia diffusa var. tetrandra (Forst.) Heimerl
C. & C.; FRF; FWS-C. Common trailing vine found in much of the open or very slightly shaded sandy area of both Sand and Eastern Islands.

Bougainvillea sp. Bougainvillea.
FWS. A few very nice vines noted growingon residential porches on Sand Island.

Portulaca lutea Sol.
C. & C.

Portulaca oleracea L. Purslane.
FWS-C; FRF. Locally abundant, widespread in open sandy areas on both Sand and Eastern Islands.

Capparis sandwichiana DC.
C. & C.

Lepidium o-waihiense C. & S.
C. & C.

Lepidium virginicum L. Pepper-grass.
FWS-C. Rare, only two or three plants noted on each of the islands.

Lobularia maritima (L.) Desv. Sweet alyssum.
FRF; FWS. Sweet alyssum grows in abundance over large portions of both Sand and Eastern Islands.

Desmodium uncinatum (Jacq.) DC.
St. J.

Medicago lupulina L. Nonesuch.
FRF; FWS. Fosberg found it growing as an escapee from a lawn. We found a few specimens about the residential area, on Sand Island.

Trifolium sp.
St. J.

Crotalaria incana L. Rattle-pod.
FWS-C. Only two or three plants were seen growing on each of the islands.

Crotalaria mucronata Desv. Rattle-pod.
St. J.

Leucaena glauca (L.) Benth. Koa haole.
FWS-C. The only plant seen was growing on the lawn of the Administration Building on Sand Island.

Acacia farnesiana (L.) Willd. Klu.
St. J.; FWS-C. Found as a planted ornamental in some places on Sand Island. One small wild spot has grown up near the enlisted men's residential area.

Albizzia lebbeck (L.) Benth. Woman's tongue.
FWS-C. Found as an ornamental and in a few scattered small wild patches about the older part of Sand Island.

Oxalis corniculata L. Sorrel.
FWS-C. Occasional, scattered about on both Sand and Eastern Islands.

Tribulus cistoides L.
C. & C.; FWS-C. Locally abundant trailing ground cover on sandy areas on both Sand and Eastern Islands.

Murraya paniculata (L.) Jack Mock orange.
FWS-C. Seen only as a planted hedge in the residential area on Sand Island.

Euphorbia geniculata Ort. Spurge.
St. J.

Euphorbia heterophylla L. Wild poinsettia.
FRF; FWS-C. Abundant on Sand Island, common as an understory among the thinner stands of ironwoods and as dense marginal growth about the edges of thick stands. Also present on Eastern Island.

Euphorbia hirta L. Spurge.
St. J.; FRF; FWS-C. Occasional or locally common. Most frequently seen in open sandy utility areas where the soil has been disturbed during recent years.

Euphorbia prostrata Ait. Spurge.
FWS-C. Seen only occasionally on Sand Island, growing along the edge of paved runways.

Euphorbia pulcherrima Willd. Poinsettia.
FWS-C. Found growing as an ornamental at one residence formerly occupied by Pan-American employees, on Sand Island.

Ricinus communis L. Castor-oil bean.
FRF; FWS. An occasional small plant was seen on Eastern Island. On Sand Island there are several fairly large patches, some of them far distant from the residential area.

Schinus terebinthifolius Raddi Christmas berry.
FRF; FWS-C. Noted only as a hedge plant on Sand Island.

Hibiscus tiliaceus L. Hau.
FWS-C. Hau trees are to be found about the residential sector on Sand Island, and one or more near the old control tower on Eastern Island. Occasional specimens occur widely scattered about the Sand Island scrub.

Hibiscus sp. Hibiscus.
FWS. Quite a few nice specimens of flowering hibiscus shrubs occur in the residential sector on Sand Island.

Malvastrum coromandelianum (L.) Garcke
St. J.; FWS-C; FRF. Occasional plants may be found about the residential area on Sand Island, and two or three are growing near the old control tower on Eastern.

Sida fallax Walp. Ilima.
C. & C.

Thespesia populnea Sol. ex Correa Milo.
FWS. One milo tree was noted growing on the lawn of the Administration building on Sand Island.

Waltheria indica L.
St. J.

Terminalia catappa L. Tropical almond; false kamani.
FWS. Scattered trees may be found almost all over Sand Island, and a few nice specimens were seen on Eastern Island.

Carissa grandiflora A. DC. Natal plum.
FWS-C. Found growing only as a hedge plant in the residential area of Sand Island.

Catharanthus roseus (L.) G. Don Periwinkle.
FWS-C. Seen only as a flowering ornamental near the old Pan-American Gooneyville Lodge on Sand Island.

Thevetia peruviana (Pers.) K. Schum. Bestill tree.
FWS-C. Found only as an ornamental in the residential area of Sand Island.

Nerium oleander L. Oleander.
St. J.; FWS-C. Seen only as an ornamental and hedge plant in the residential area of Sand Island.

Ipomoea indica (Burm.f.) Merr. Morning glory.
C. & C.; FWS-C. Growing profusely near one residence on Sand Island. Several plants growing near an old building in the revetment area on the south shore of the island.

Ipomoea pes-caprae (L.) Sweet Beach morning glory.
C. & C. FWS-C. Locally common, this plant is most often found in open sandy areas in the interior of both islands, or along the sandy upper beach-lines.

Messerschmidia argentea (L.f.) Johnston Tree heliotrope.
FRF; FWS-C. Not uncommon, but widely scattered on both Sand and Eastern Islands. Often seen emerging above the Scaevola scrub.

Lantana camara L. Lantana.
FWS-C. Found only as a hedge and ornamental plant in the residential and administrative area of Sand Island.

Stachytarpheta jamaicensis (L.) Vahl . False vervain.
St. J.

Vitex trifolia var. bicolor (Willd.) Mold.
FRF; FWS-C. Found only as an ornamental planting in the residential area on Sand Island.

Phyllostegia variabilis Bitter
C. & C.

Solanum nigrum L. Nightshade.
St. J.; FRF; FWS-C. Occasional, found mostly in utility areas about buildings.

Solanum laysanense Bitter
C. & C.

Solanum nelsoni var. intermedium F. Br.
C. & C.

Plantago lanceolata L. Plantain.
St. J. While this plant was reported 20 years ago, the senior author, thoroughly familiar with it at home, did not find it.

Scaevola frutescens (Mill.) Krause Naupaka.
C. & C.; FRF; FWS-C. Abundant. The dominant vegetation of both islands. It is gradually creeping to the tops of the old revetments, recapturing areas lost to military destruction. Where undisturbed, in vacant lot, and in waste land.

Conyza bonariensis (L.) Cronq. Horseweed.
St. J.; FRF; FWS-C. Locally abundant, mostly along the margins of runways and unpaved roadways; also noted in utility areas where the sand has been disturbed, in vacant lots, and in waste land; on both Sand and Eastern Islands.

Gnaphalium purpureum L. Purple cudweed.
FRF. Very rare, found in the shade of a building at the Air Terminal on Sand Island.

Gnaphalium sandwicensis f. canum Sherff
FWS-C. Locally common along margins of runways and in old administrative areas on Eastern Island, and thinly but widely scattered in similar locations on Sand Island.

Pluchea odorata (L.) Cass.
FRF; FWS-C. More widespread on Eastern Island than on Sand Island, but abundant on both. This weed species has taken over many open areas where the soil was disturbed by construction work, such as along the margins of runways, and now forms an almost impenetrable barrier to heights of four to five feet.

Bidens pilosa L. Spanish needle.
FRF. Dr. Fosberg found it common in weedy ground on Sand Island.

Sonchus oleraceus L. Sow thistle.
FRF; FWS-C. Rare; only an occasional plant was seen growing along utility toads and in service areas on both Sand and Eastern Islands.

Xanthium saccharatum Wallr. Cocklebur
St. J. We knew of St. John's report of cockleburs on Midway, but did not find the plant.

Verbesina encelioides Gray
FRF; FWS-C. Abundant on both islands, though more widespread on Eastern than on Sand. Forms a dense cover on many of the open areas in the interior of the islands, taking over areas that would be better vegetated if in grasses. Offers the only bit of color on the islands with its multitude of golden blossoms.

The plants reported herein represent 35 families and 91 species. Of these, 24 species listed in the 1931 and 1935 papers were not seen by either Dr. Fosberg or the authors in 1954. Their present status is therefore unknown. In addition to these, Hadden (1941) and Bryan (1942) listed a variety of plants that had grown on Midway, some of them by common name. We did not find the following group of plants listed by Hadden and Bryan:

Kou	Baobab	Coprosma	Flame tree	Papaya
Tamarix	Brassaia	Cypress	Acalypha	Dieffenbachia
Sanseveria	Panax	Plumeria	Ti	Pinus, Oregon forms.
Limes	Dracaena	Buttonbush	Croton	

The Midway Islands of today are a different sight than that seen by the early explorers, or the first Cable Company employees of fifty years ago. There is little expanse of glaring white sand. As the plane approaches the islands, and as the newcomer catches his first glimpse of them, his first reaction is to note the geometric pattern of runways, and the second is to comment that these are green islands, not deserts. As the plane comes

closer the green of the uneven forest of Casuarina and the Scaevola scrub begins to outline the working facilities of the islands, and as the plane sinks down onto the runway it flashes, in early November, past bright golden Verbesina growing along the runway's edge and in the open spaces. We board the bus and drive into the shaded ironwood section that is the residential portion of Sand Island, where, as we listen to the ocean breeze through the ironwoods, we may easily forget that we have travelled to the islands Midway of the north Pacific and think ourselves back home again - until the bus driver slams on the brakes and we wait while a strolling gooney bird parades across the road. Whereupon we either smile or cuss a bit, and say "This is Midway."

Literature cited

Bryan, E. H., Jr.
American Polynesia and the Hawaiian Chain.
1-253, Honolulu, 1942.

Christophersen, E. and Caum, E. L.
Vascular plants of the Leeward Islands, Hawaii.
Bishop Museum Bulletin 81: 1-41, 1931.

DuMont, P. A.
Gooneybird studies on Midway.
Elepaio 15(9): 52-55, 1955.

Hadden, F. C.
Midway Islands.
The Hawaiian Planters' Record 45: 179-221, 1941.

St. John, H.
Additions to the flora of the Midway Islands.
Bishop Museum Occasional Paper 11(14): 1-4, 1935.

U. S. Fish and Wildlife Service
Denver, Colorado and
Washington, D. C.

ATOLL RESEARCH BULLETIN

No. 46

Conspicuous features of organic reefs

by

J. I. Tracey, Jr., P. E. Cloud, Jr. and K. O. Emery

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences—National Research Council

Washington, D. C.

August 15, 1955

Conspicuous Features of Organic Reefs[1/]

by

J. I. Tracey, Jr.,[2/] P. E. Cloud, Jr.,[2/] and K. O. Emery[3/]

Introduction

Cooperative studies of Pacific reefs, especially in the last 10 years, have brought together oceanographers, biologists, and geologists, each dependent on the work of others and each to some degree inconvenienced by the diversity of names used to denote parts of reefs. The nomenclature of even the conspicuous features of reefs has varied widely. Although the field is much too active for stabilization in detail to be practicable, agreement is desirable for those features of reef and lagoon that appear to be generally present and therefore especially important in reef studies. The following list is purely utilitarian and descriptive; it is not intended as a comprehensive terminology with established priority of usage.

The immediate stimulus to this paper was provided by D. P. Abbott, Marston Bates, F. M. Bayer, and R. R. Harry of the Pacific Science Board's 1953 Ifaluk Atoll team, who worked up a set of names and discussed them with Tracey at Ifaluk and Guam. Discussion of these and other terms by Tracey, Cloud, and Emery at Manila in November 1953 led to the circulation of a provisional draft of the present paper to 17 colleagues for review and criticism. The replies were generally favorable and the comments that were received on specific features and terms helped greatly in preparing the final revision.

The following list, then, sets forth what we consider to be the most widely distinctive zones or features of reefs, illustrated by a hypothetical cross-section of an atoll (fig. 1). The zonation of barrier reefs (which are separated by a lagoon from preexisting land) and of fringing reefs (which border preexisting land) is close enough to that of atoll reefs so that most of the names are generally applicable.

Discussion

An atoll consists of a ring-shaped organic reef that encloses a lagoon in which there is no preexisting land, and which is surrounded by the open sea. The primary distinctions to be drawn are between outer slope, reef, island, lagoon, and smaller reef structures within the lagoon.

1/ Publication authorized by the Director, U. S. Geological Survey.

2/ U. S. Geological Survey, Washington 25, D. C.

3/ U. S. Geological Survey, University of Southern California, Calif.

Channels and passes between ocean and lagoon are also of primary importance. Most of the difficulty with names, especially for those who must rely on collections and data gathered by others, lies in boundaries between the principal zones. The following terms are suggested, with purposely broad definitions:

1. Outer slope.--the steeply descending outer slope of the reef below the dwindle point of abundant living coral and coralline algae, which is ordinarily at about 10 fathoms.

2. Reef front.--the upper seaward face of the reef, extending above the dwindle point of abundant living coral and coralline algae to the reef edge. This zone commonly includes a shelf, bench, or terrace that slopes to 8-15 fathoms, as well as the living, wave-breaking face of the reef. The terrace may be an eroded surface or may be veneered with organic growth. The living reef front above the terrace in some places is smooth and steep; in other places it is cut by grooves separated by ridges that together have been called groove and spur systems, forming comb-tooth patterns. If the terrace is broad and well defined it may be well to designate it a separate reef zone.

3. Seaward reef margin.--the seaward edge of the reef flat, marked in places by an algal ridge and cut by surge channels, which are the landward extensions of the reef-front grooves.

4. Reef flat.--the upper surface of the reef, commonly exposed or awash at lowest tide. The presence of islands on the flat modifies the ecology of the reef; therefore, an important distinction should be drawn between island reef flats, or flats seaward from islands, and inter-island reef flats or flats between islands.

   The reef flat is commonly divisible into outer and inner reef flats, or outer, central, and inner reef flats; but one "inner" or "outer" zone may not be the close ecologic equivalent of another "inner" or "outer" zone.

   On inter-island reefs, and on seaward reef flats adjoining islands, the outer zone is toward the ocean, the inner is toward lagoon or shore. In rare instances a broad reef flat on the lagoon shore of an island may be subdivided into an outer lagoon reef flat, near the lagoon reef edge, and an inner lagoon reef flat, near the island; but careful distinction should be made between its parts and those of reef flats that abut the open sea. If a reef flat is not present on the lagoon side of an island, its place may be taken by a lagoon shelf, on which detrital sediments predominate over organic growth.

5. Seaward beach.--the seaward-facing beach of reef islands.

6. Lagoon beach.--the lagoonward-facing beach of reef islands.

7. Lagoon reef margin.--the lagoonward margin of the reef; unlike the seaward reef margin, it is not necessarily defined by growth. In some places, especially where islands are present, there may be no lagoon reef margin at all. If the lagoon reef margin is well defined, a lagoon reef front may be present and even a lagoon terrace, comparable to the seaward reef front and terrace. If the lagoon reef margin is poorly defined, a lagoon shelf may separate lagoon slope from reef flat or lagoon beach (fig. 2).

8. Lagoon slope.--the border zone of the lagoon that slopes downward from the lagoon reef margin or lagoon beach to the lagoon floor.

9. Lagoon floor.--the undulating to nearly level floor of the lagoon.

Minor organic prominences on lagoon floors or slopes, all broadly related, range from small mounds or tall narrow pinnacles to large masses, hundreds of feet in diameter. Some prefer to use a single term for all such features, for example, coral knoll, bioherm, or patch reef. The considerable physical and organic variety of these features is ecologically significant, however, and should be indicated in some way. In general it seems preferable to use informal names that will describe both the dominant organism and the physical appearance. Examples are: algal knoll; coral-algal mound; millepore patch; Acropora thicket, etc.

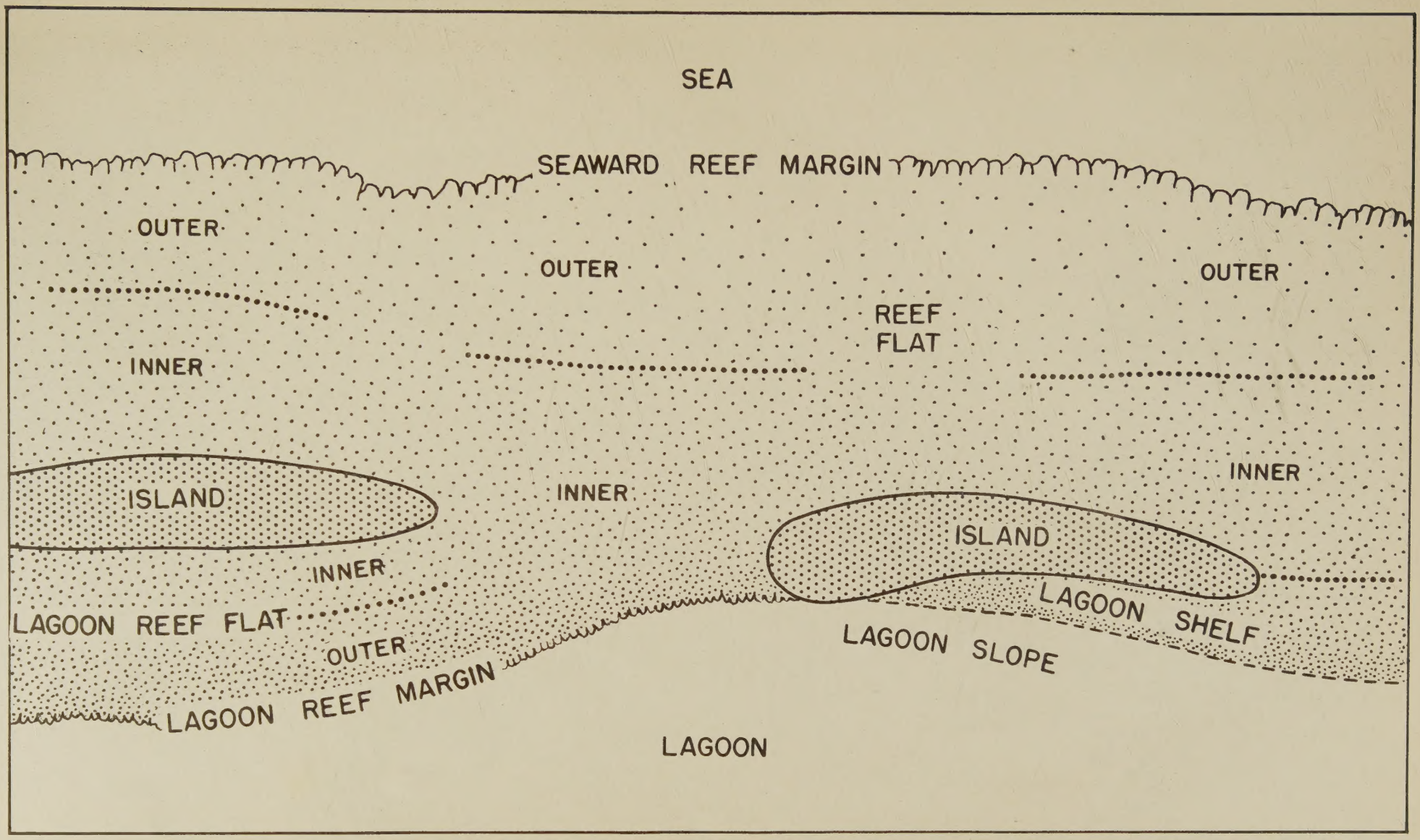


FIGURE 2. COMMON SUBDIVISIONS OF UPPER REEF SURFACE SEEN IN PLAN VIEW